Radiobiological Research of the Laboratory of Radiation Biology

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Laboratory of Radiation Biology

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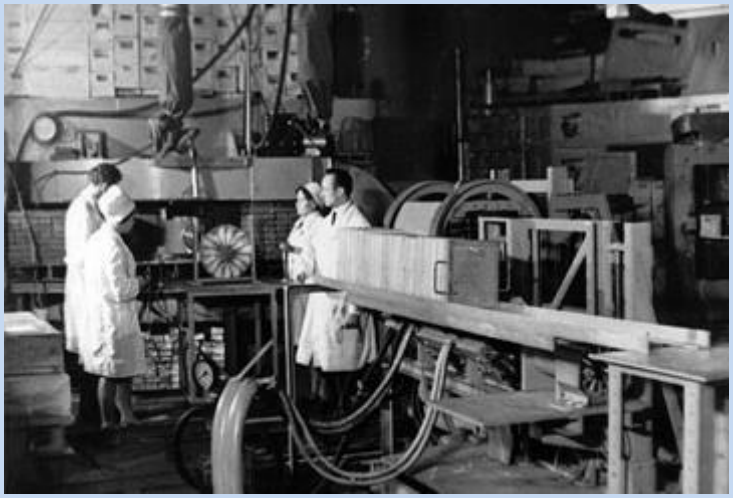
JINR history and present

- 1959 first radiobiological experiments LNP
- 1978 Sector of Biological Research Laboratory of LNP
- 1988 Department of Biophysics at LNP
- 1995 Department of Radiation and Radiobiological Research of JINR
- 2005 Laboratory of Radiation biology



Laboratory of Radiation biology

- Molecular Radiobiology
- Radiation Cytogenetics
- Group of Lower Eukaryote Radiation Genetics
- Photoradiobiology
- Mathematical modeling
- Astrobiology
- Radiation Neurochemistry
- Radiation Physiology

Research fields of LRB

- Radiation genetic studies – mammalian and human cells
- Radiation research and development
- Computer molecular modeling of biophysical systems
- Radiobiological studies of the Retina and Crystalline lens, cataract induction, visual pigment studies
- Cosmic radiation research, specialized research of CNS
- Astrobiological research

Research on the Biological Effect of Heavy Charged Particles with Different Energies

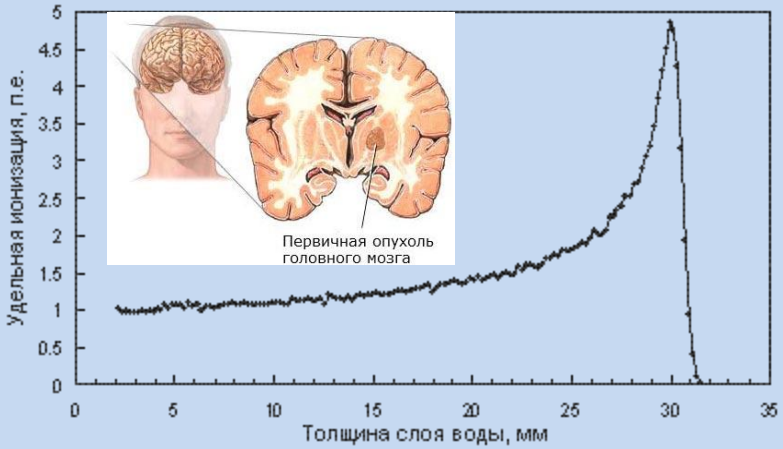
Nuclotron, ^{12}C 500 MeV/amu

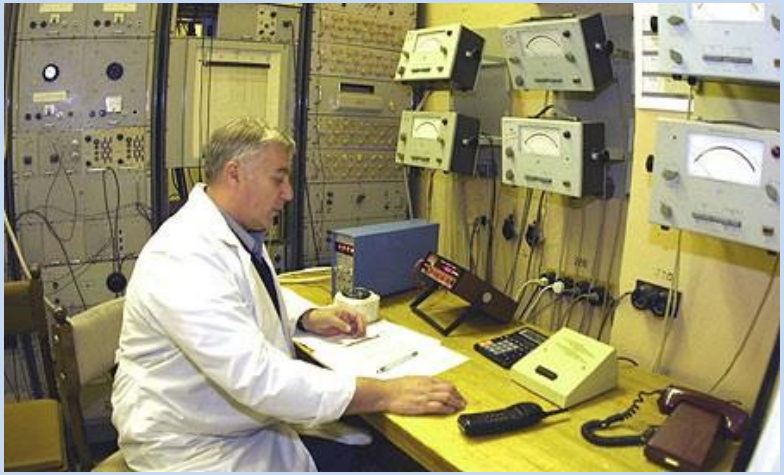
Phasotron, protons 170 MeV

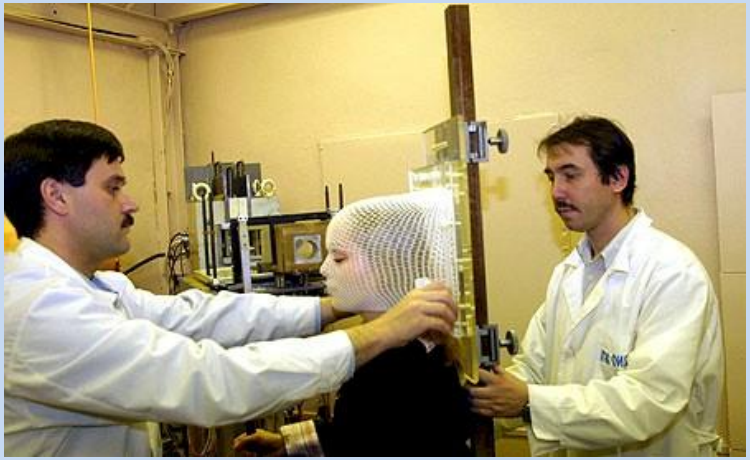
U-400M, up to 50 MeV/u Li, B, Ne ions

Radiation therapy

Medical and Technical Complex of JINR



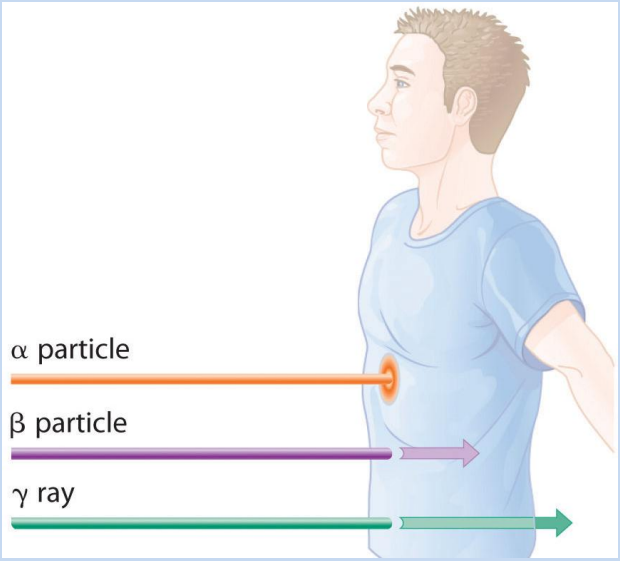


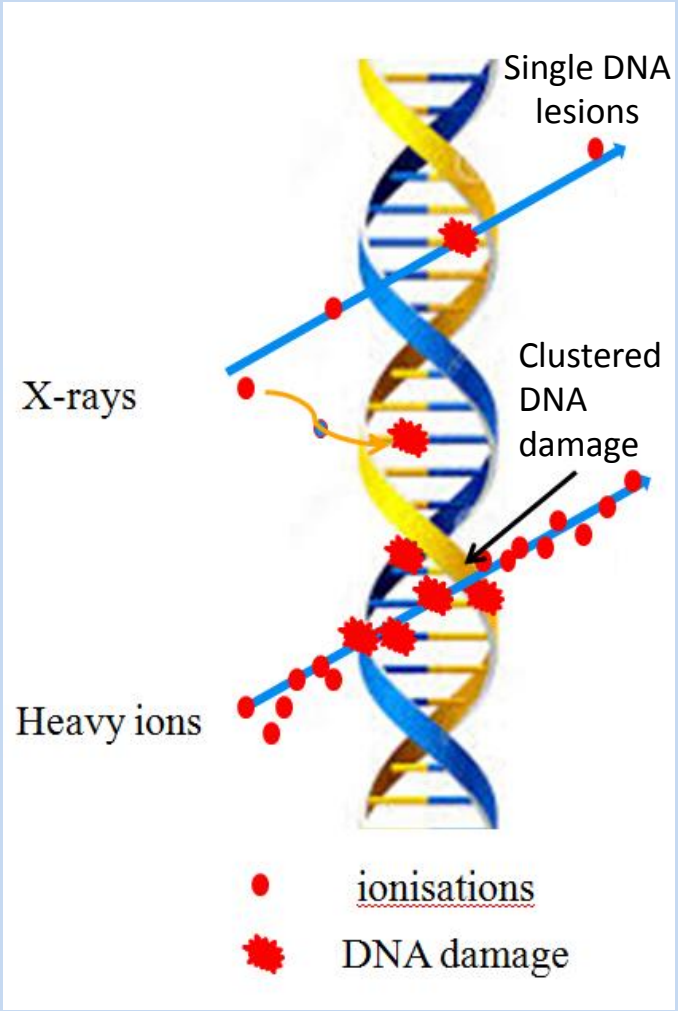


Radiation: sources and biological effects

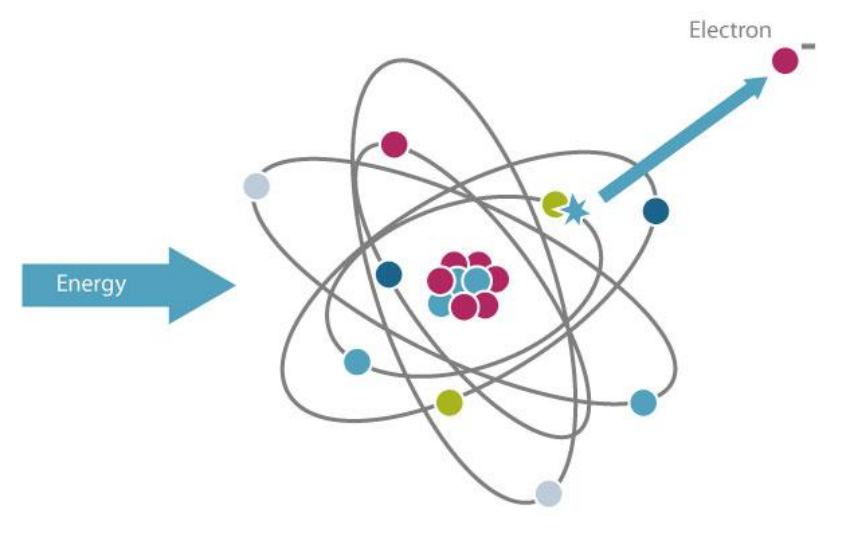
- Electromagnetic radiation, plane travels, medical radiation, cosmic radiation

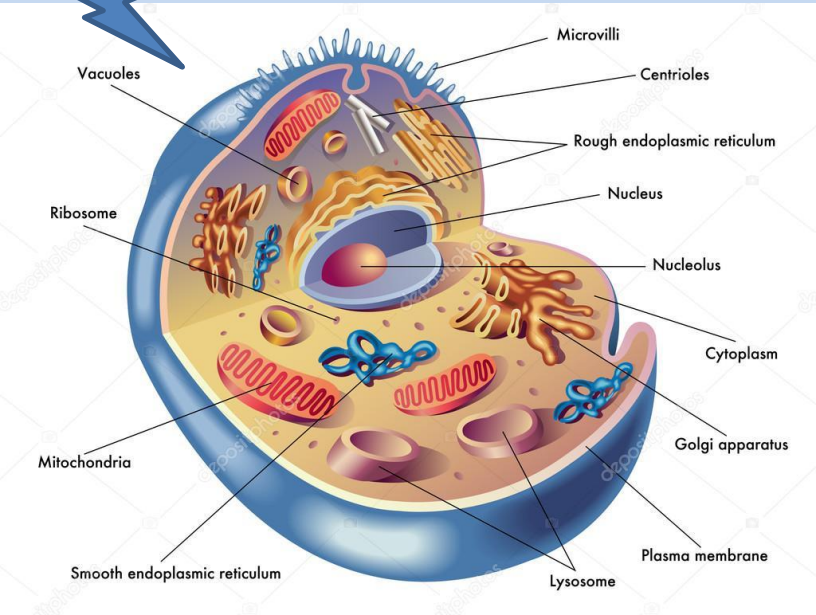
- Cell damage – free radicals formation – DNA damage – cell death/ mutations

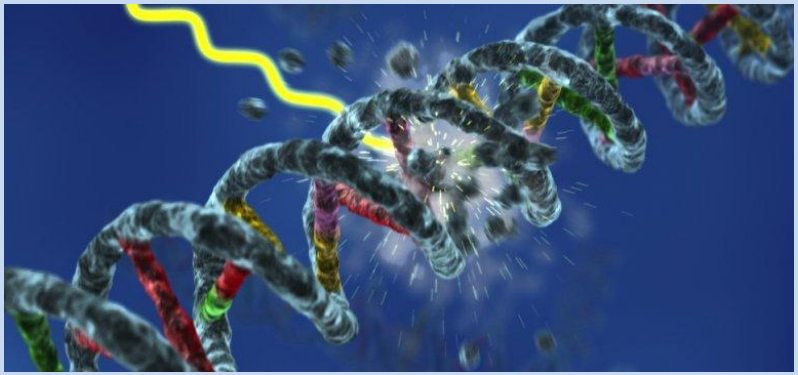




Radiation: effects in the cell







DNA damage

Peroxides, superoxides

Effects of radiation

- Early Effects:

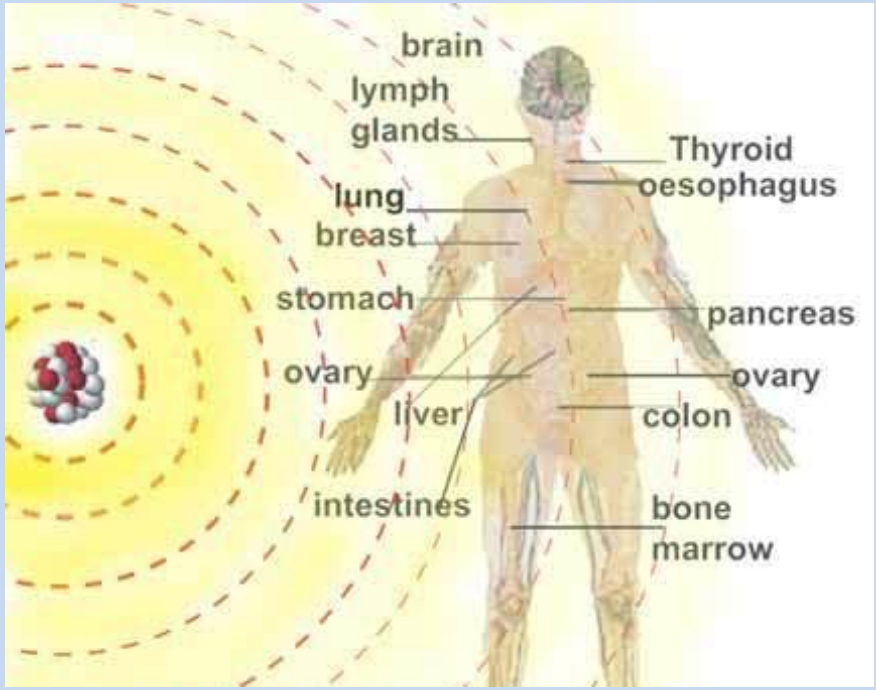
- radiation response occurs within minutes/days after exposure
- acute radiation syndrome, local tissue damage

- Late Effects:

- radiation response observable after months or years
- local tissue damage, leukemia, cataracts, cancers, CNS damage, life span shortening, sterility

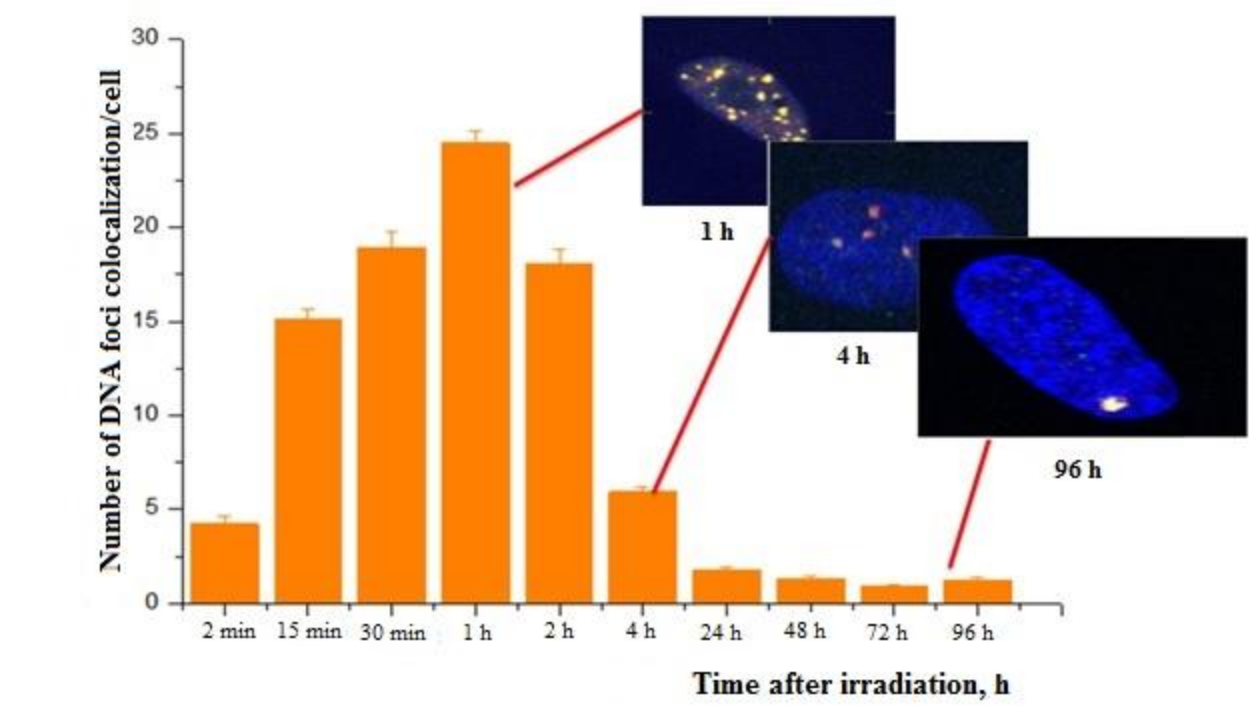
- Genetic Effects:

- teratogenesis, mutagenesis



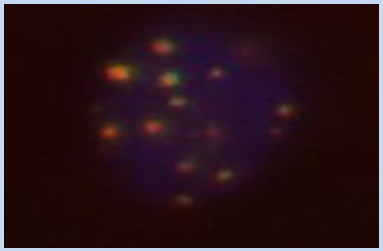
Radiation immunocytochemistry

γ-rays

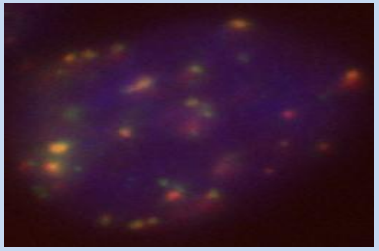


Double strand break induction (53BP1 and γH2AY foci) in human skin fibroblasts after irradiation with accelerated ^{20}Ne ions

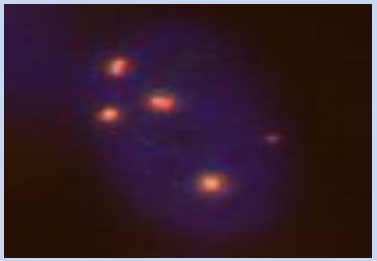
^{20}Ne ions, 50 MeV/nucleon



30 min



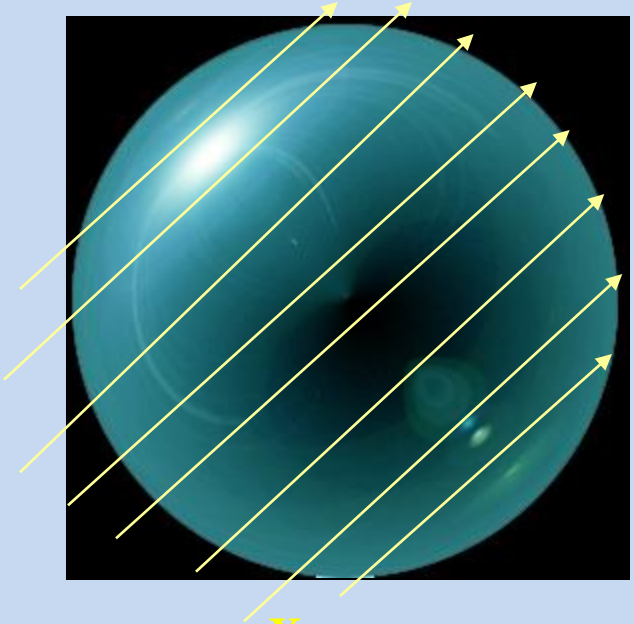
6 h



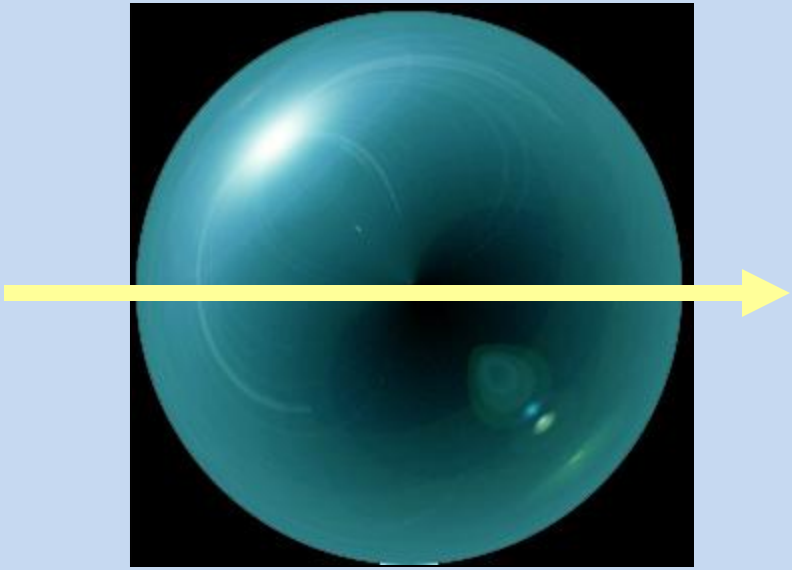
48 h

The dose distribution of radiation in matter

1 unit of the dose

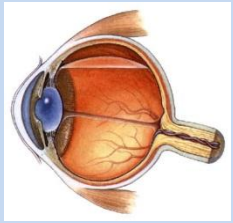


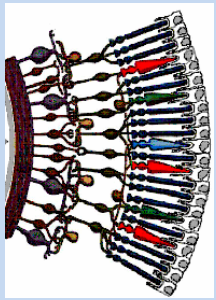
X-rays



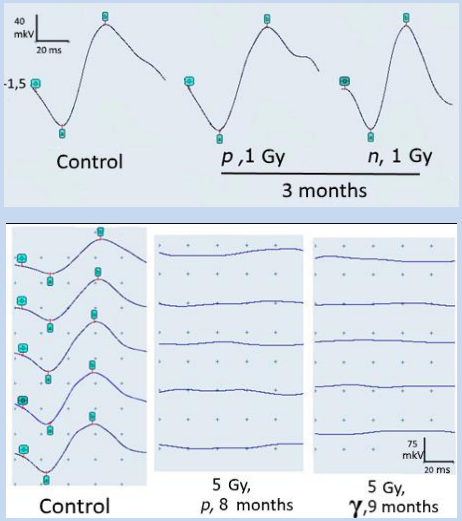
Fe ion

Damage of eye structures by accelerated charged particles

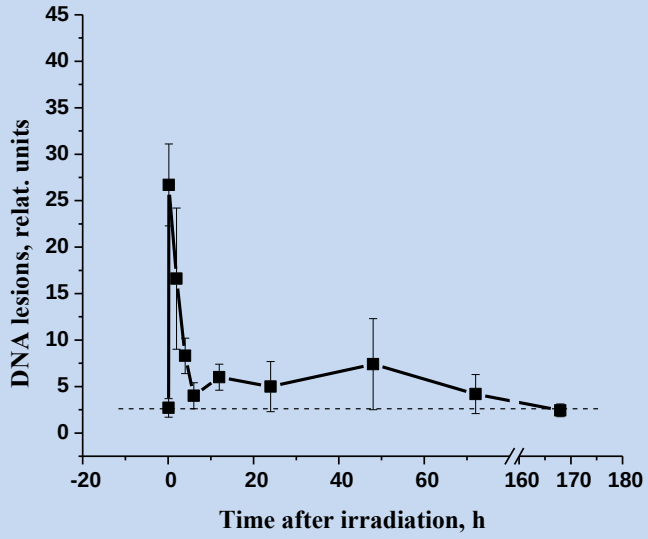




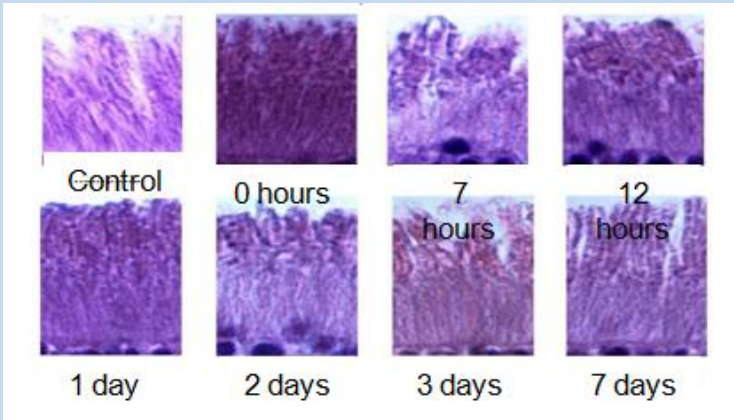
DNA lesions in retina cells after proton (170 MeV) irradiation



Functional activity of the eye retina of mice after exposure to low doses of ionizing radiation

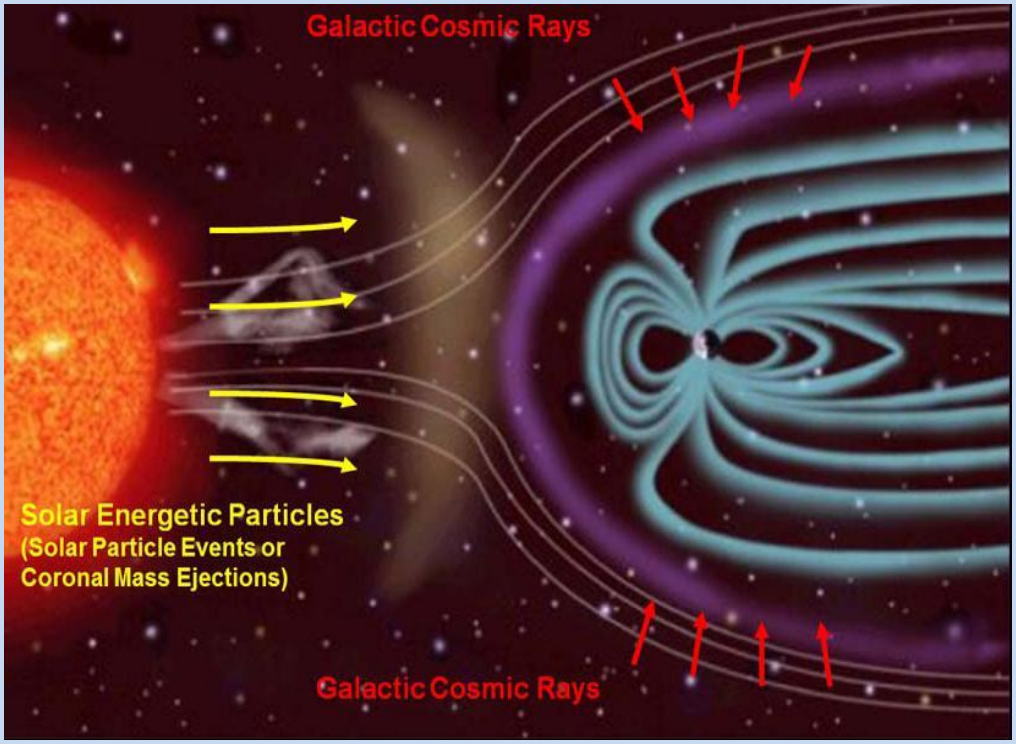


Dynamics of ***morphological changes*** in the retina after proton irradiation

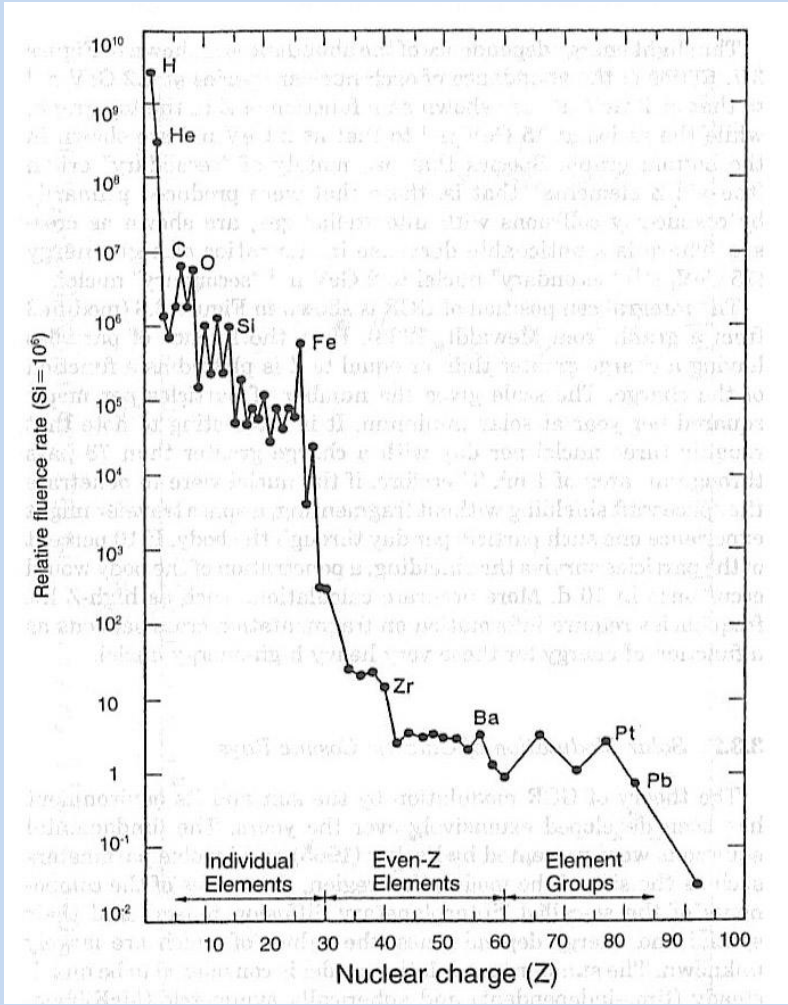


Cosmic radiation

- Solar energetic particles, galactic cosmic rays (protons-92%, nucleus of helium atoms-7%, heavy nuclei), stardust (exploding stars)
- Secondary neutrons and charged particles are the major sources of radiation exposure in an interplanetary spacecraft



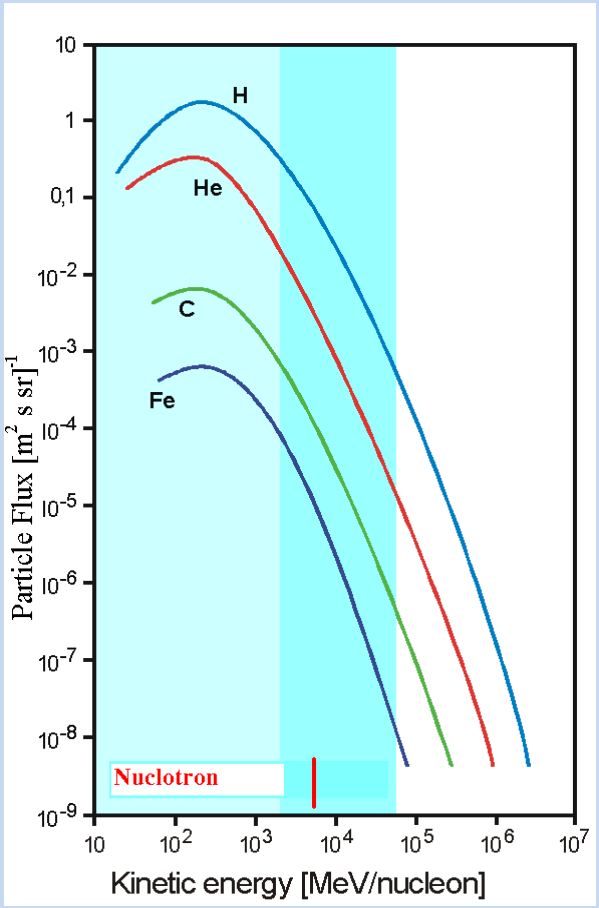
Composition of Galactic Cosmic Radiation



LRB Cosmic radiation research

The radiation barrier for manned missions into Deep Space and modeling of biological action of space radiation at accelerators of heavy ions

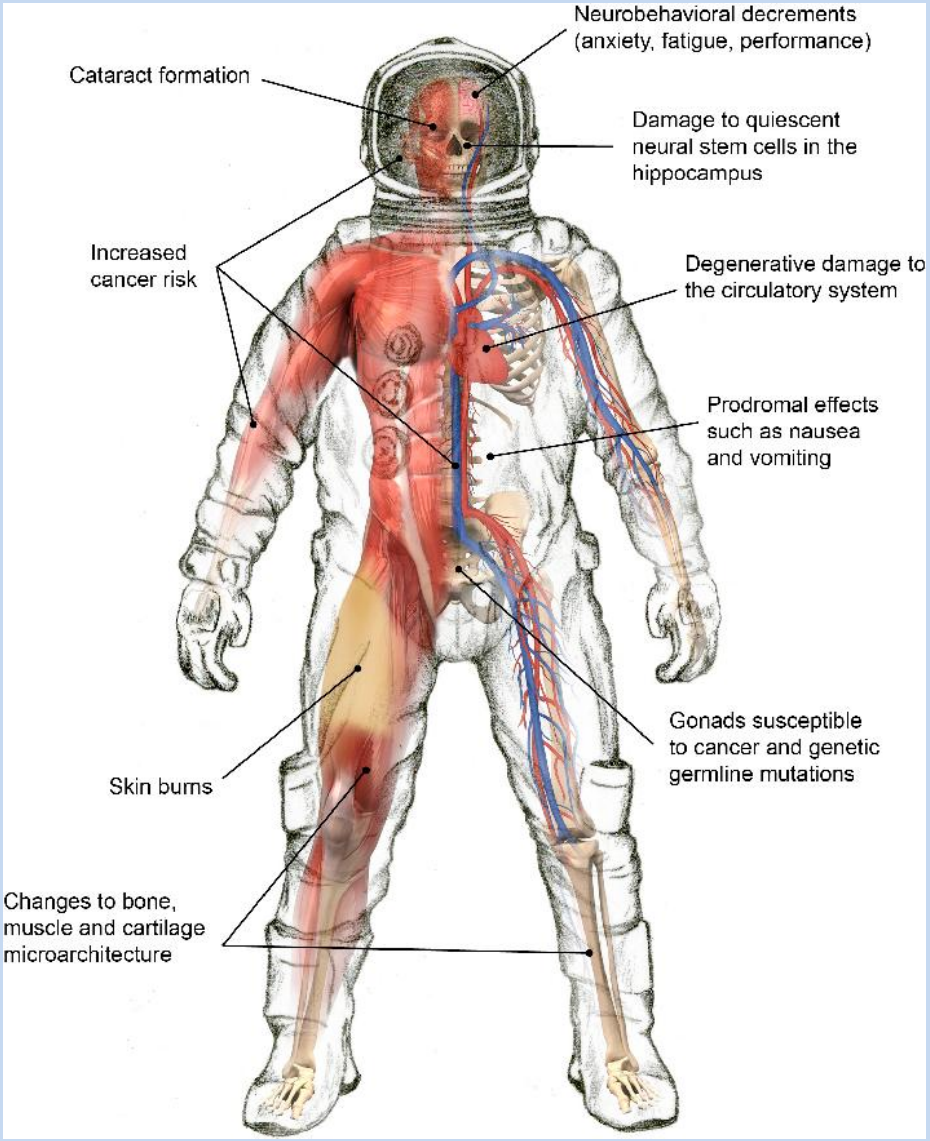
The energy spectrum of GCR

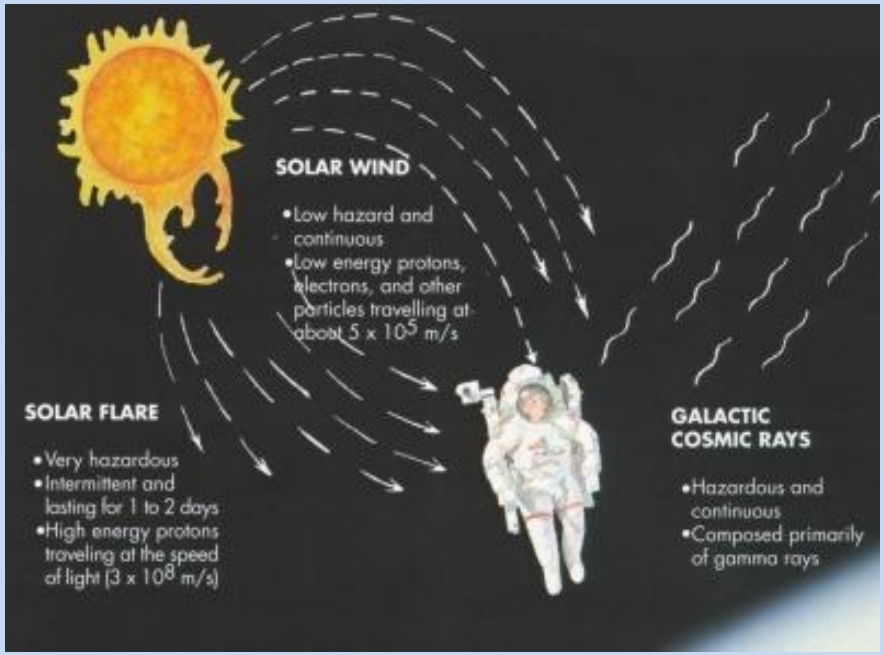


The integral flux of GCR particles of carbon and iron groups equals to *10^5 part/cm^2 per year*

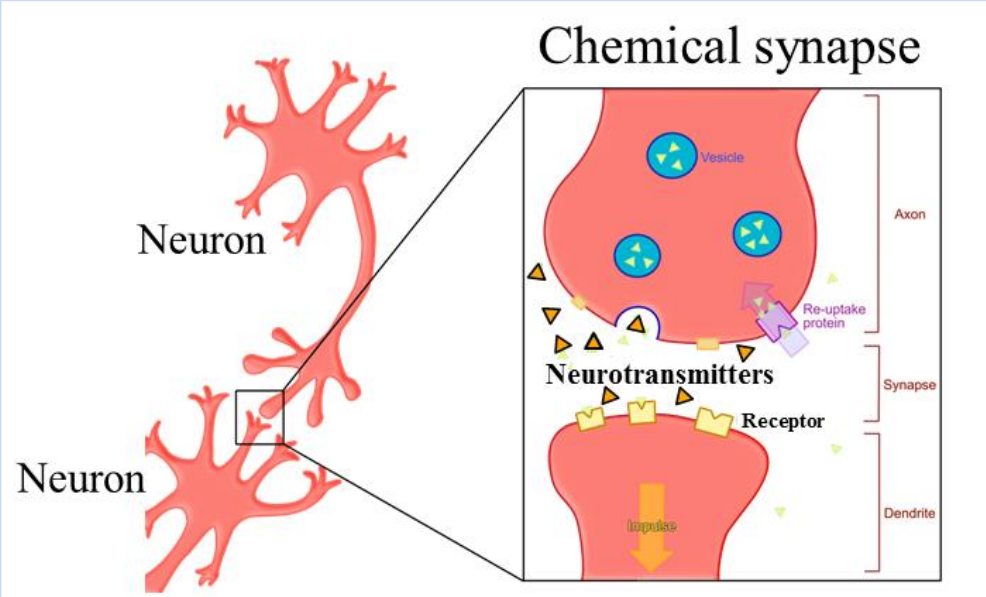
Particle flux density interplanetary space z≥20
160 per day per cm^2

Body & Brain under cosmic radiation





- In CNS: damage to the glutamatergic transmission in the hippocampal synaptosomes; a significant decrease in the expression of the NR1, NR2A and NR2B subunits of the glutamatergic NMDA receptor

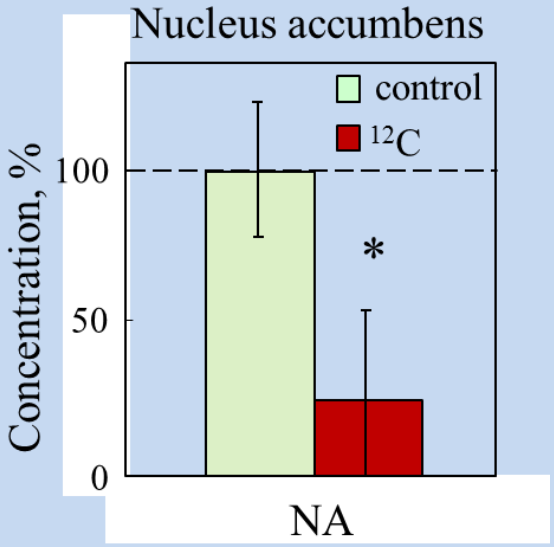


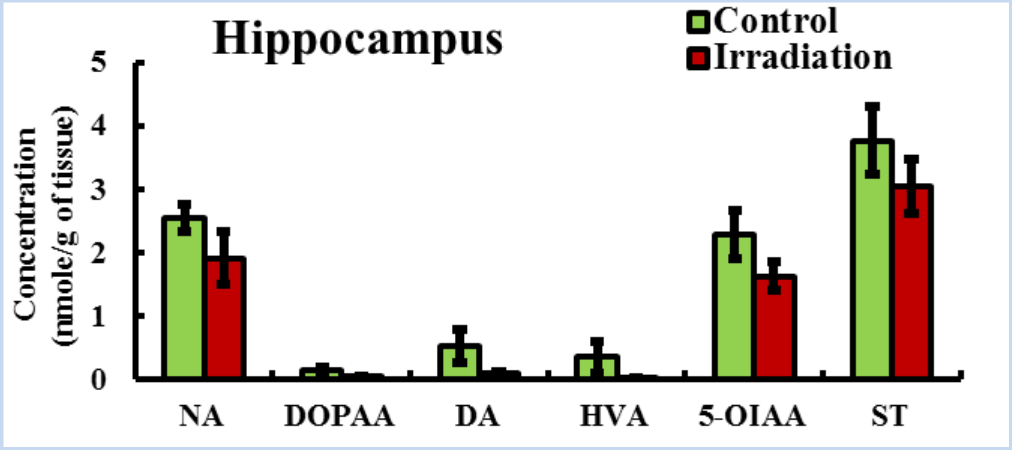
Irradiation with 1 Gy of 500 MeV/u carbon ions

- Radiation-induced decrease in the level of neurotransmitters is observed in the brain regions responsible for the emotional and motivational state

  (radiobiological experiments at the Nuclotron-M; effect of accelerated heavy ions on the functional activity of the CNS)

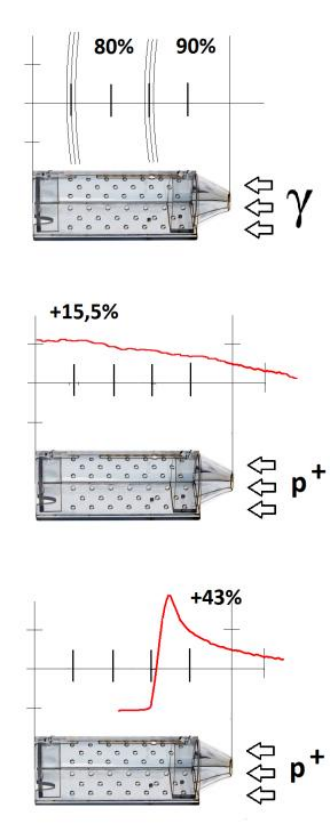
3 months after irradiation

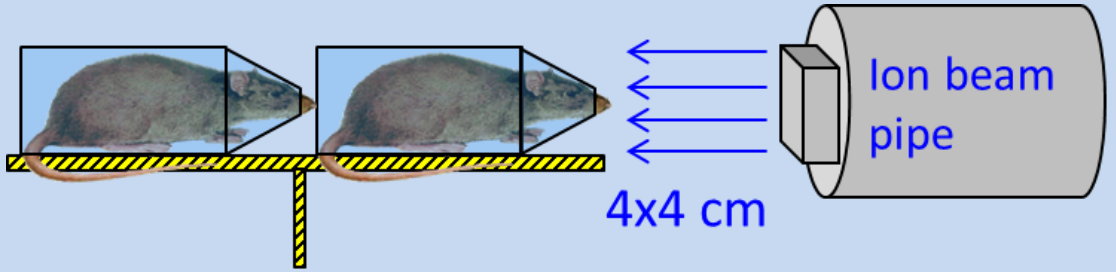


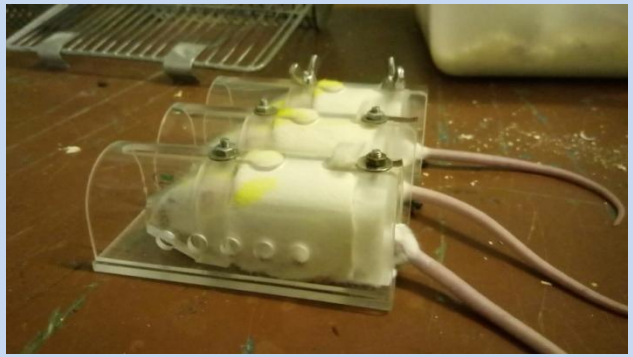


Radiobiological Experiments

- heavy ion-induced functional and morphological disorders in the CNS
- neurochemical studies of the brain neurotransmitter metabolism in rats after exposure to ^{12}C ions and γ-rays
- molecular and genomic damage under irradiation
- research on retina damage in mice by accelerated charged particles





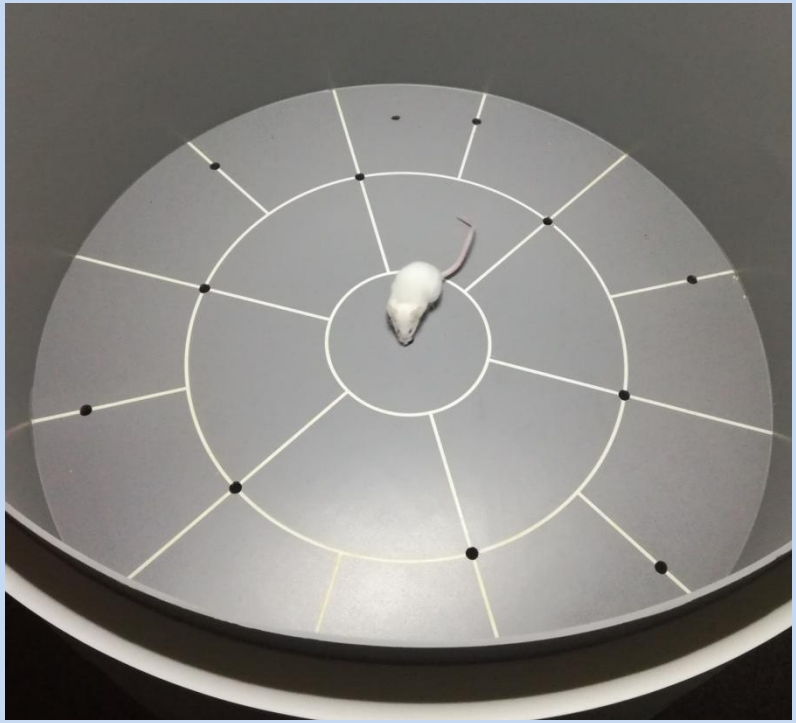


Gamma irradiation

Proton irradiation

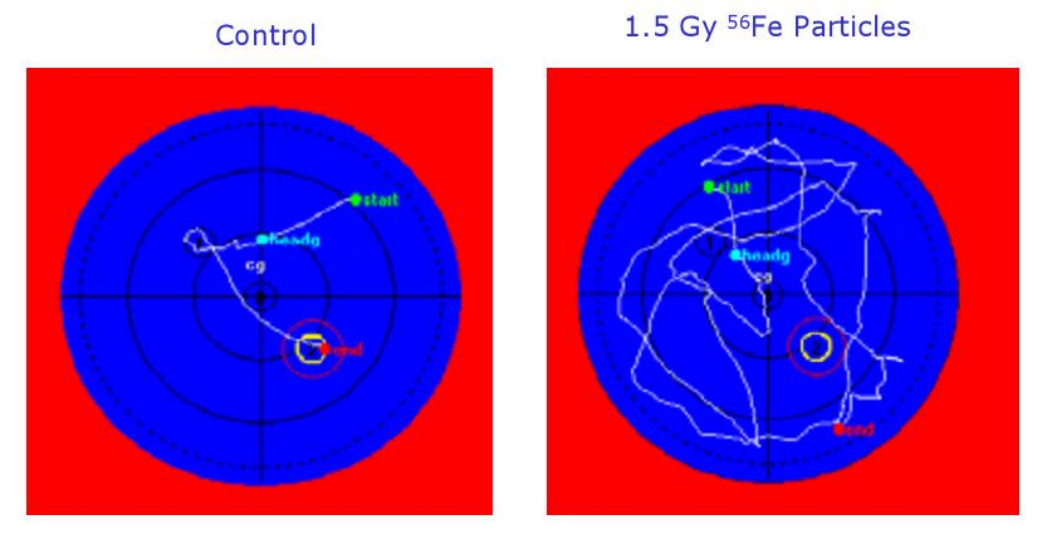
Cognitive-behavioral tests

Open Field



Barnes Maze

Morris water maze test

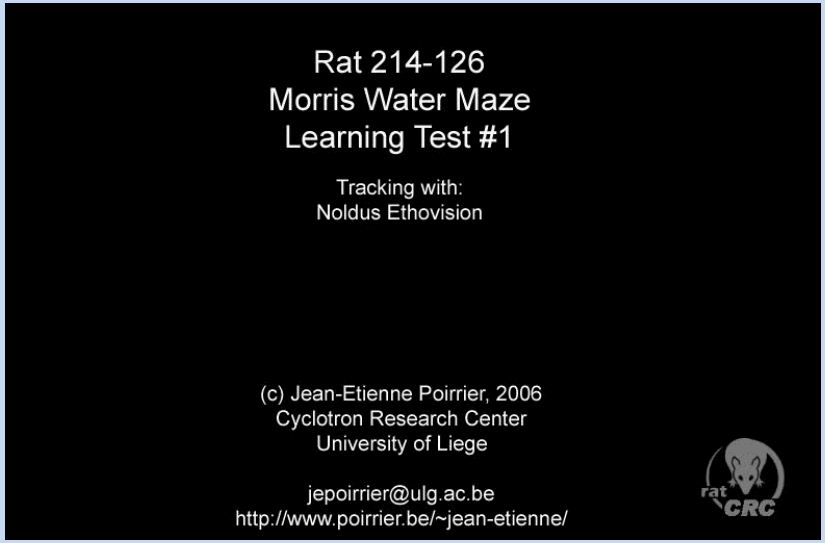


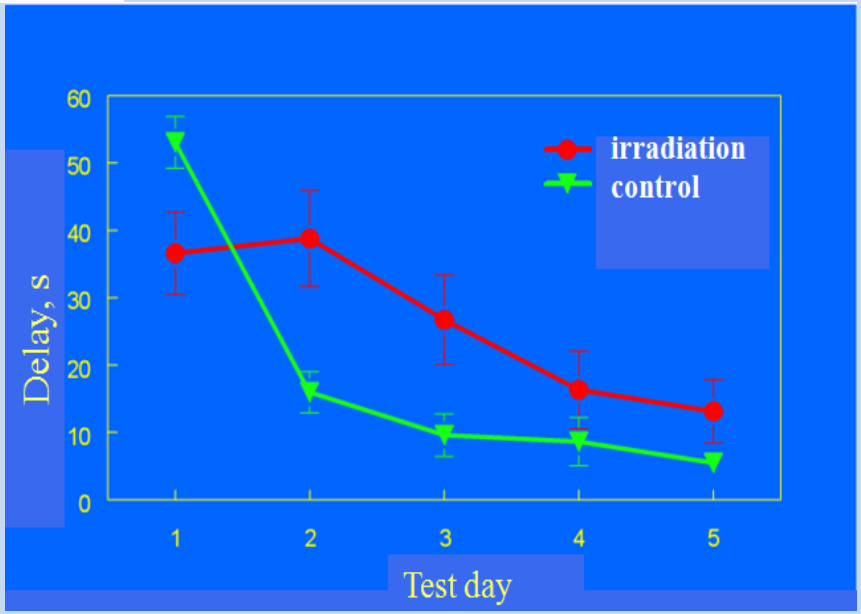
^{56}Fe ions, 1 GeV/amu

1,5 Gy

1 month after irradiation

M.Rabin, 2005

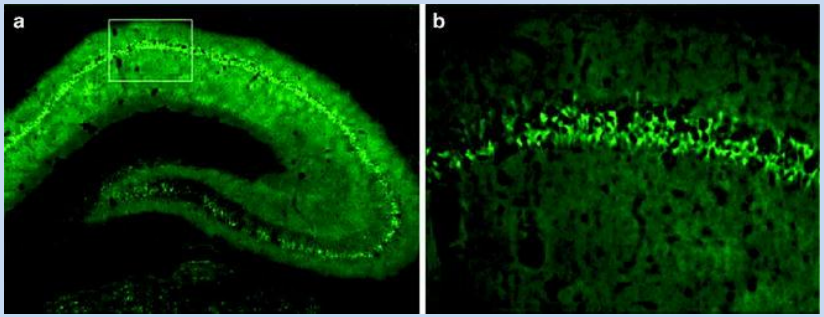


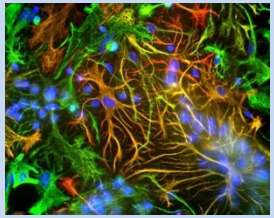


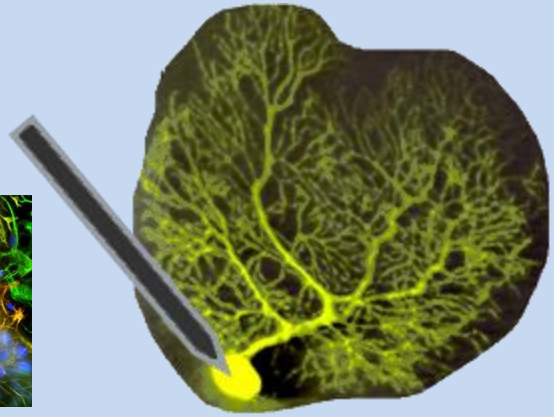
Morphology, histology, biochemistry

Nissl staining

Fluoro Jade B







The effect of 1 Gy ^{12}C particle radiation exposure on rats

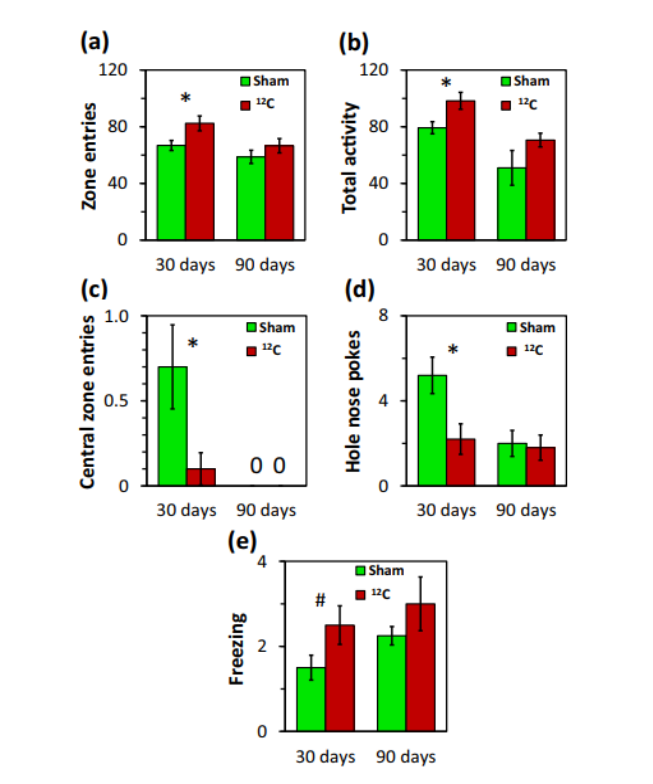


Fig. 1 The open field test results - including zone entries (a), total activity (b), central zone entries (c), hole nose pokes (d), and freezing frequency (e). (/) $p < 0.05$ and (#) $p < 0.1$ between the exposed and sham-irradiated rats at the same periods of time after exposure

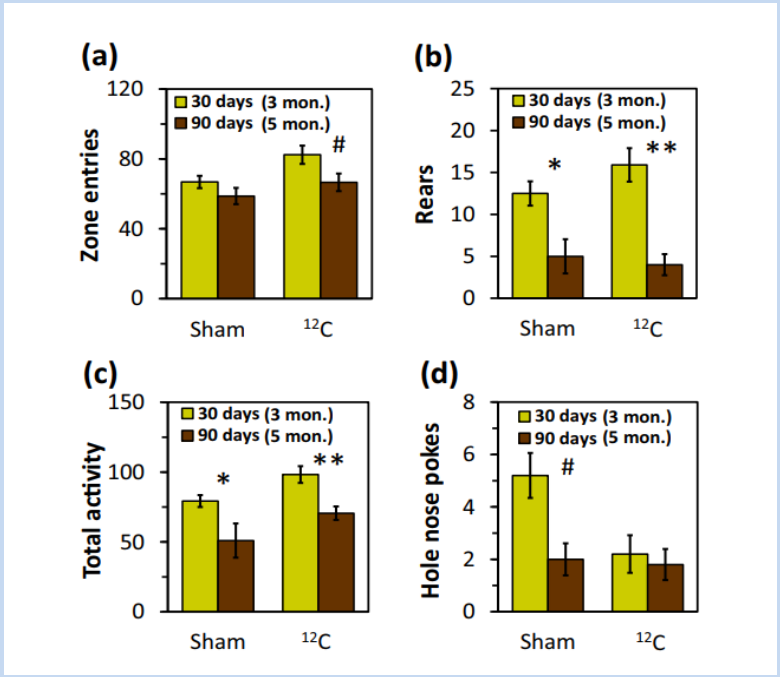
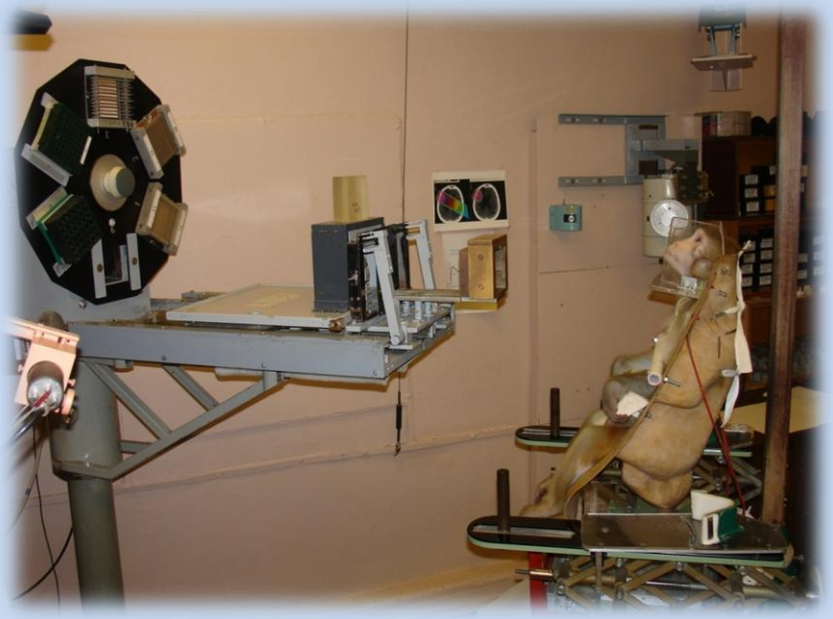


Fig. 2. The temporal dynamics of the open field test - including zone entries (a), rearings (b), total activity (c), and hole nose pokes (d). (/) $p < 0.05$, (//) $p < 0.01$, and (#) $p < 0.1$ between 3- and 5-month-old rats in the exposed and sham-irradiated groups. The corresponding periods after exposure were 30 and 90 days, respectively.

Experiments with monkeys

Proton irradiation with medical beam, 170 MeV, 3 Gy

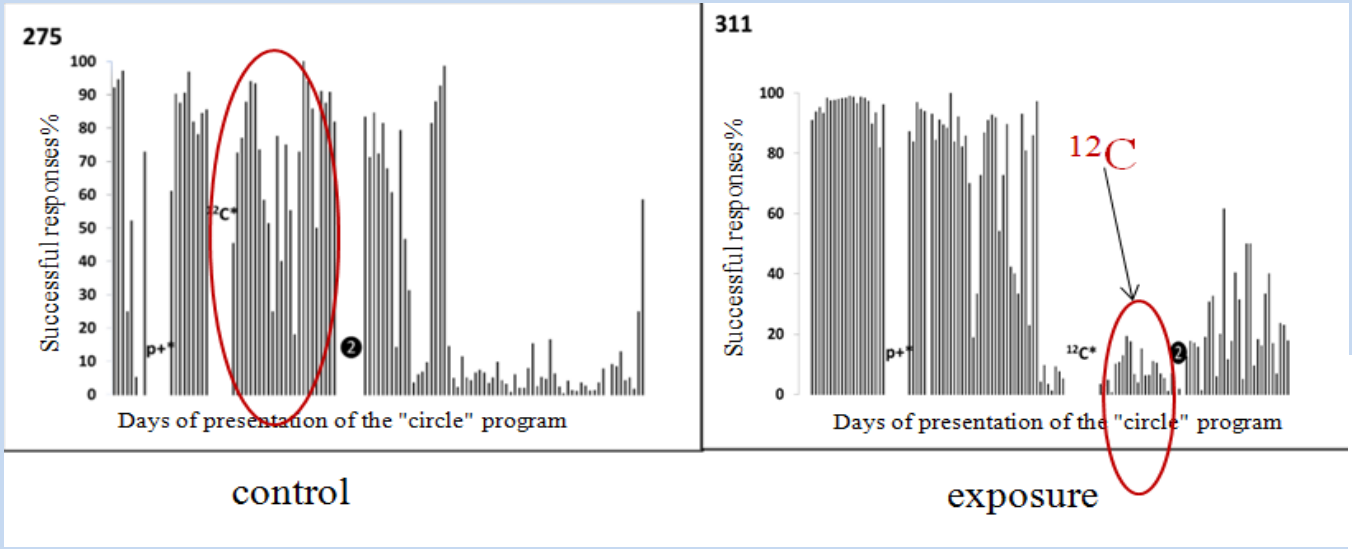
Irradiation with ^{12}C ions, 500 MeV/u, at the Nuclotron, 1 Gy



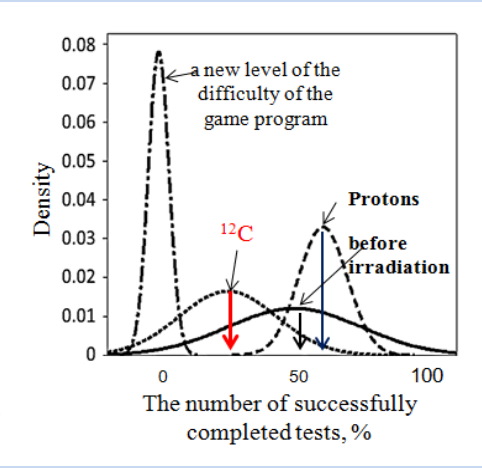
Macaca mulatta irradiation (^{12}C ions, 500 MeV/nucleon)

Psychological Test System — a series of 18 computer gaming tasks of increasing difficulty to simulate the basic elements of the operator's activity

Indicators of cognitive functions in the irradiated and control monkey groups

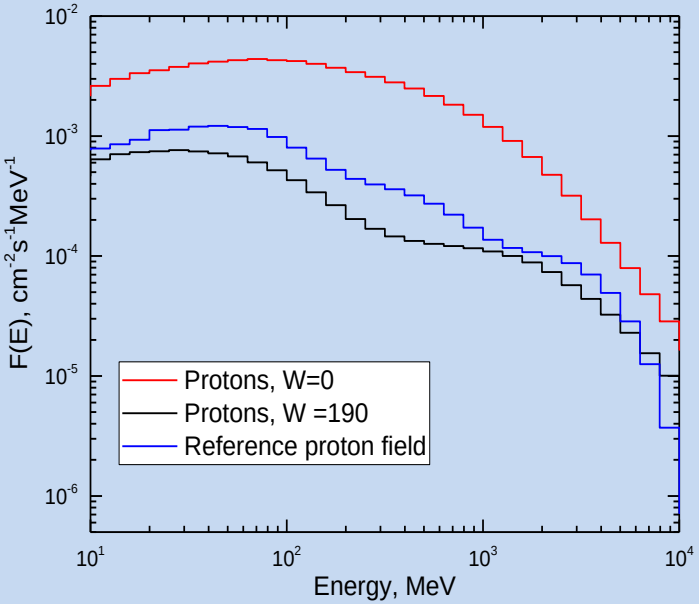


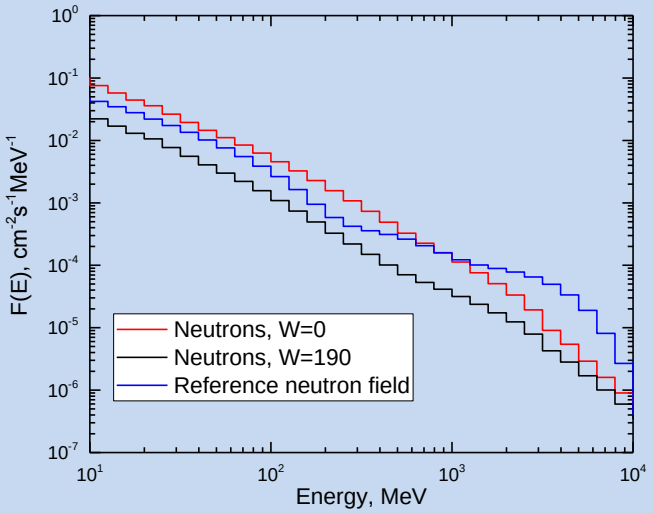
Dose: 1 Gy



p + — proton irradiation day; ^{12}C — carbon ion irradiation day; 2 — a new level of the game program difficulty.

NUCLOTRON BASED SIMULATION OF RADIATION ENVIRONMENT ON THE BOARD OF SPACECRAFT IN DEEP SPACE





Modeling the actual conditions of radiation in space with accelerated-based radiation experiments

The methods based on the linear combination of energy spectra of the particles emitting at various angles from three different targets, consecutively bombarded by 10 GeV proton beam.

The used risk concept

Based on the introduction of a **generalized dosimetric functional** as the criterion and quantitative measure of radiation danger

Generalized dose H_I and H_D for the evaluation of, respectively, the *immediate adverse consequences* during the flight and the *delayed consequences* during the rest of life:

$$H_{\mathrm{I}} = \left(\sum_{i=1}^{n} \overline{D}_i \quad \mathrm{KK}_{\mathrm{I}i} \quad \mathrm{KB}_{\mathrm{I}i} \quad \mathrm{KP}_{\mathrm{I}i} \right) \mathrm{KM}_{\mathrm{I}}$$

$$H_{\mathrm{D}} = \left(\sum_{i=1}^{n} \overline{D}_i \quad \mathrm{KK}_{\mathrm{D}i} \quad \mathrm{KB}_{\mathrm{D}i} \quad \mathrm{KP}_{\mathrm{D}i} \right) \mathrm{KM}_{\mathrm{D}}$$

KK$_i$ – *radiation quality* coefficients;

KB$_i$ – coefficient taking into account the *dose distribution over time*;

KP$_i$ – coefficient taking into account the *dose distribution over the human body*;

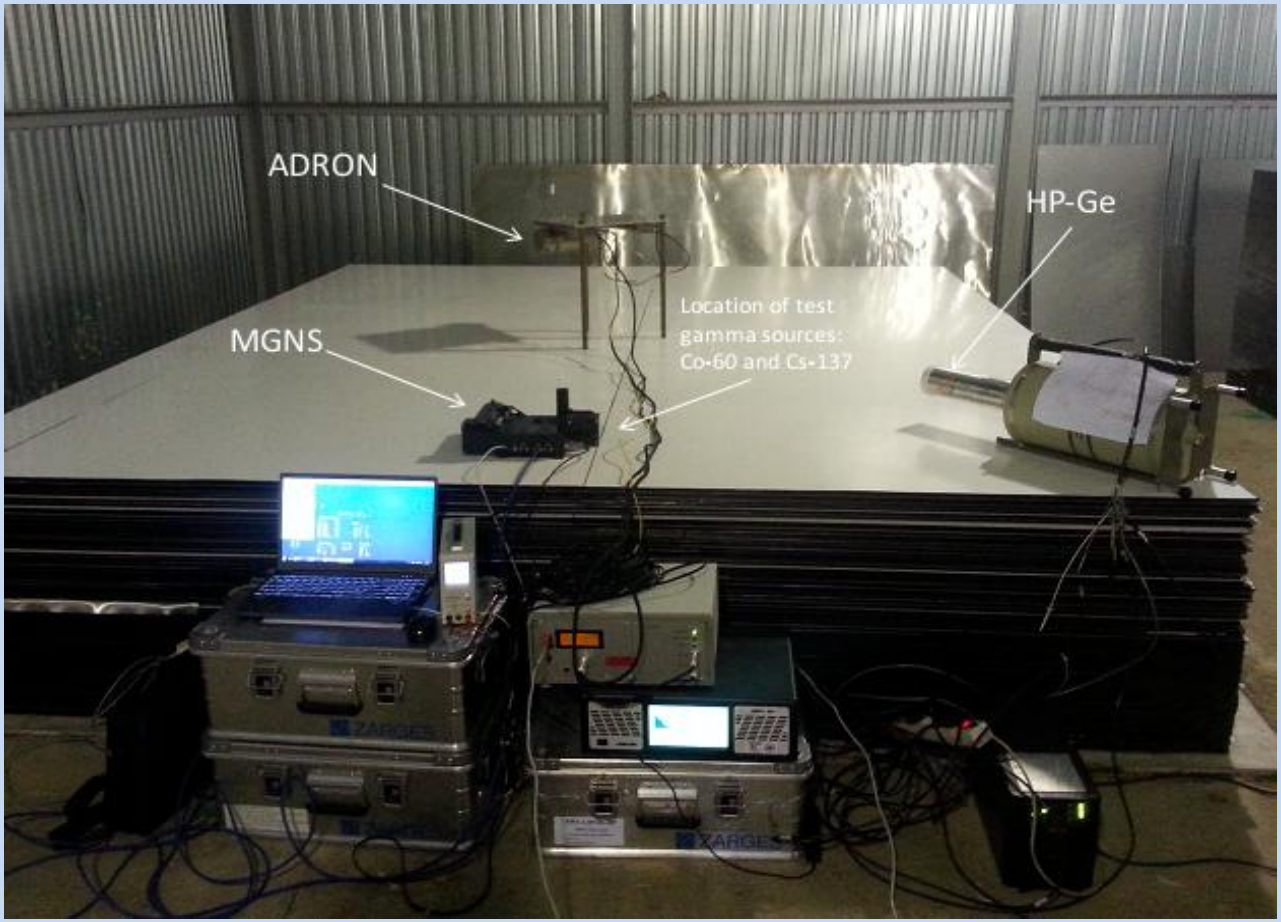
KM – coefficients of the organism's radiation response modification caused by *other factors* of the space flight.

The probability of successful mission implementation

$$P = 1 - \left(P_{rad.\ damage} + P_{non\text{-}rad.\ injury} + P_{tech.\ failure} - P_{rad.\ damage} \cdot P_{non\text{-}rad.\ injury} - P_{rad.\ damage} \cdot P_{tech.\ failure} - P_{non\text{-}rad.\ injury} \cdot P_{tech.\ failure} + P_{rad.\ damage} \cdot P_{non\text{-}rad.\ injury} \cdot P_{tech.\ failure} \right)$$

$$P_{rad.\ damage} = P_{CNS}(H(t),t) + P_{rad.sickness}(H(t),t) - P_{CNS}(H(t),t) \cdot P_{rad.sickness}(H(t),t)$$

Nuclear planetary science

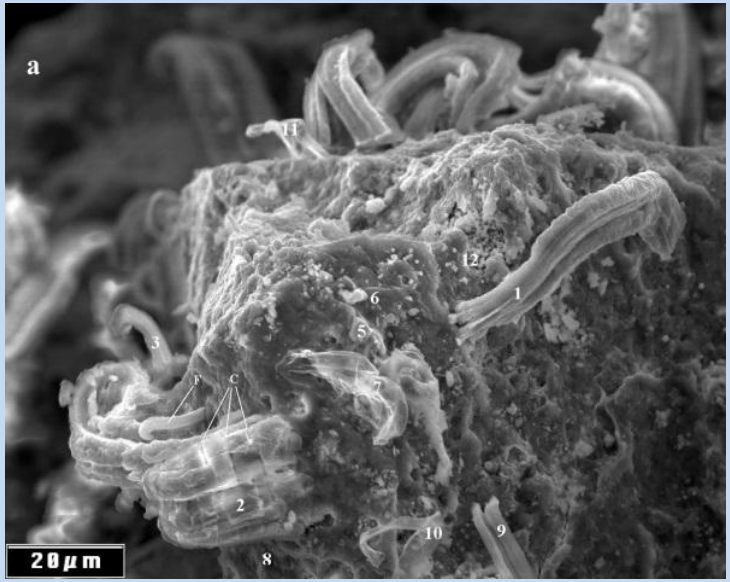


In collaboration between the Space Research Institute (RAS) and FLNP (JINR), a ***special facility has been constructed*** at the LRB that can ***model planetary soil*** and allows testing prototypes of active neutron and gamma spectrometers.

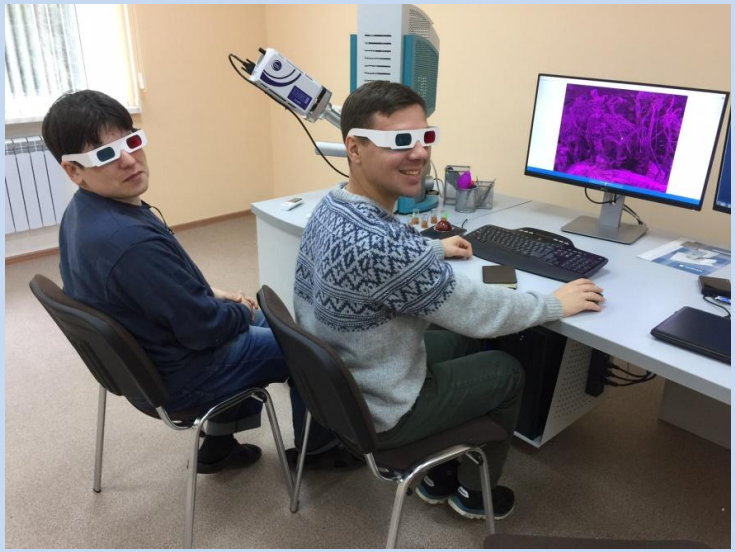
The facility can use a neutron generator for soil model exposure. Inside the facility, a silicate glass-based soil model has been assembled.

Astrobiology

SEM Tescan Microscope



Orgueil CI1 Meteorite, biofossils



Thank you for your attention!