Joint institute
for Nuclear Research

Veksler and Baldin Laboratory of High
Energy Physics

Nuclotron-based Ion Collider fAcility

Applied Research Infrastructure
for Advanced Developments at NICA fAcility

Applied research at NICA facility: Status of ARIADNA infrastructure and related scientific programme

Oleg Belov

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Joint Institute for Nuclear Research

Joint Institute for Nuclear Research

International intergovernmental organization

Established on **26 March 1956** and registered with the United Nations
Located in Dubna, Russian Federation

Joint Institute for Nuclear Research

SCIENCE BRINGING NATIONS TOGETHER

JINR IS A MEMBER OF **39** COLLABORATIONS AT SCIENTIFIC CENTRES AROUND THE WORLD

>900 PARTNER NETWORK ORGANIZATIONS

JINR in Figures:

- 19 Member States
- 5260 staff members
- 1200 researchers
- 1000 Doctors and Candidates of Sciences
- 2000 engineers and technicians
- 1500 scientific publications per year
- over 70 international conferences and workshops per year
- 800 partner universities, educational and research centres in more than 70 countries

Unique Park of Basic Facilities:

- World's Top Pulsed Neutron Source
- Heavy Ion Accelerators in a Wide Energy Range
- Megascience Project: Superconducting Collider NICA

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

Frank Laboratory of Neutron Physics
flnph.jinr.ru

Veksler and Baldin Laboratory of High Energy Physics
lhep.jinr.ru

Flerov Laboratory of Nuclear Reactions
flerovlab.jinr.ru

Dzhelepov Laboratory of Nuclear Problems
dlnp.jinr.ru

Meshcheryakov Laboratory of Information Technologies
lit.jinr.ru

Bogoliubov Laboratory of Theoretical Physics
theor.jinr.ru

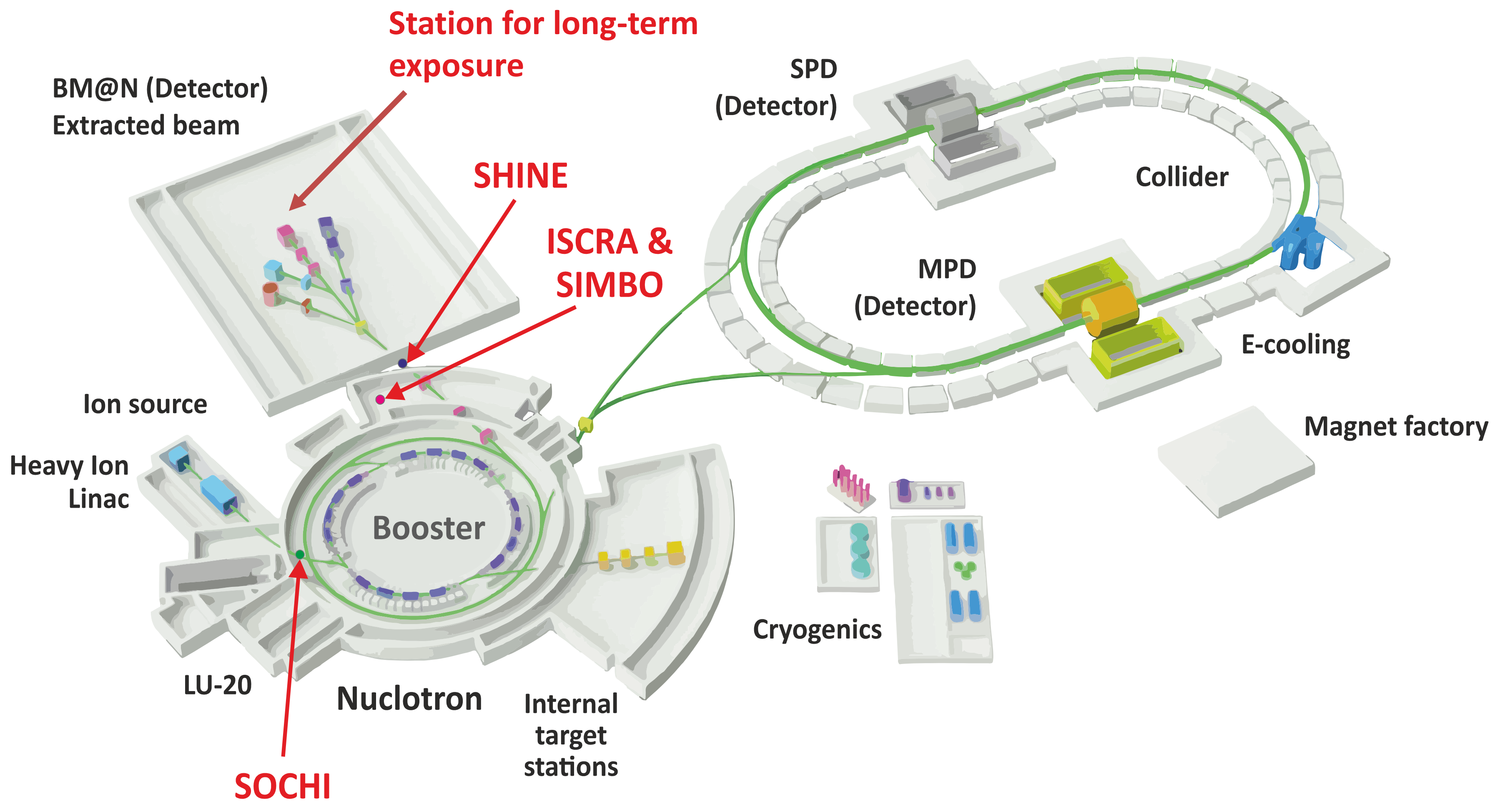
Laboratory of Radiation Biology
lrb.jinr.ru


NICA MEGASCIENCE PROJECT
NICA
2024

APPLIED RESEARCH AND INNOVATIONS @ NICA

The Applied Research Infrastructure for Advanced Developments at NICA fAcility (ARIADNA)

ARIADNA
beamlines



Applied Research and Innovations @ NICA

The Applied Research Infrastructure for Advanced Developments at NICA fAcility (ARIADNA) will include:

(1) Beamlines with magnetic optics, power supplies, beam diagnostics systems, cooling systems, etc.

(2) Experimental zones equipped with target stations for users (detectors, sample holders, irradiation control and monitoring system, etc.)

(3) Supporting user infrastructure (areas for deployment of user's equipment, for sample preparation and post-irradiation express analyses, etc.)

Low-energy ion beams available at HILAC 3.2 MeV/nucleon	Intermediate-energy ion beams available at Nuclotron 150-1000 MeV/nucleon	High-energy ion beams available at Nuclotron up to 4.5 GeV/nucleon
Life sciences, Radiation damage to microelectronics, Materials science, Novel relativistic nuclear technology		

Protons and ions with *Z* = 2 to 92

Irradiation of decapsulated microcircuits and solid materials with 3.2 MeV/nucleon ions.

Ions: $^{12}C^{6+}$, $^{40}Ar^{18+}$, $^{56}Fe^{26+}$, $^{84}Kr^{36+}$, $^{131}Xe^{54+}$, $^{197}Au^{79}$

Irradiation of capsulated microcircuits with 150-350 MeV/nucleon ions. Ions like $^{197}Au^{79+}$ are decelerated in the capsule to 5-10 MeV/nucleon.

500-1000 MeV/nucleon ions be available at the target station for biological sample irradiation.

Ions: $^{1}H^{1+}$, $^{2}D^{1+}$, $^{12}C^{6+}$, $^{40}Ar^{18+}$, $^{7}Li^{3+}$

Target station will be equipped with targets from C to Pb and with the systems of beam and target diagnostics, positioning, thermometry, synchronization, radiation control, and data acquisition.

ARIADNA COLLABORATION TODAY

ARIADNA-LS Collaboration	ARIADNA-MSTE Collaboration	ARIADNA-NPT Collaboration
The Collaboration is being established in order to perform experiments in the field of life sciences at the NICA Complex with the ARIADNA beamlines	The Collaboration is being established in order to perform activities and experiments in radiation materials science and radiation testing of electronics at the NICA Complex with the ARIADNA beamlines	The Collaboration is being established in order to facilitate study of accelerator driven subcritical reactor systems with the use of ARIADNA beamlines

Collaborating organizations

1. Joint Institute for Nuclear Research (Dubna, Int.)
2. Institute of Biomedical Problems, RAS (Moscow, Russia)
3. Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency (Moscow, Russia)
4. Skobeltsyn Research Institute of Nuclear Physics, Moscow State University (Dubna, Russia)
5. Saint Petersburg State University (Saint Petersburg, Russia)
6. Tsyb Medical Radiological Research Centre (Obninsk, Russia)
7. Semenov Research Center of Chemical Physics, RAS (Moscow, Russia)
8. Institute of Theoretical and Experimental Biophysics, RAS (Moscow, Russia)
9. Moscow Institute of Physics and Technology (Dolgoprudny, Russia)
10. Institute of Nuclear Physics, AS RUz (Tashkent, Uzbekistan)
11. Kurnakov Institute of General and Inorganic Chemistry, RAS (Moscow, Russia)
12. National Research Nuclear University MEPhI (Moscow, Russia)
13. Joint Institute of High Temperatures, RAS (Moscow, Russia)
14. North Ossetian State University (Vladikavkaz, Russia)
15. Institute of Nuclear Problems of the Belarusian State University (Minsk, Belarus)
16. CANDLE SRI, Yerevan, Armenia
17. Yerevan State University, Yerevan, Armenia
18. A.I. Alikhanyan National Science Laboratory (Yerevan Physics Institute), Yerevan, Armenia
19. RUDN University, Moscow, Russia
20. LLC Research and production company “Kvant-R” (Moscow, Russia)
21. LLC “S-Innovations” (Moscow, Russia)
22. LLC “SOL-Instruments” (Minsk, Belarus)

182 participants

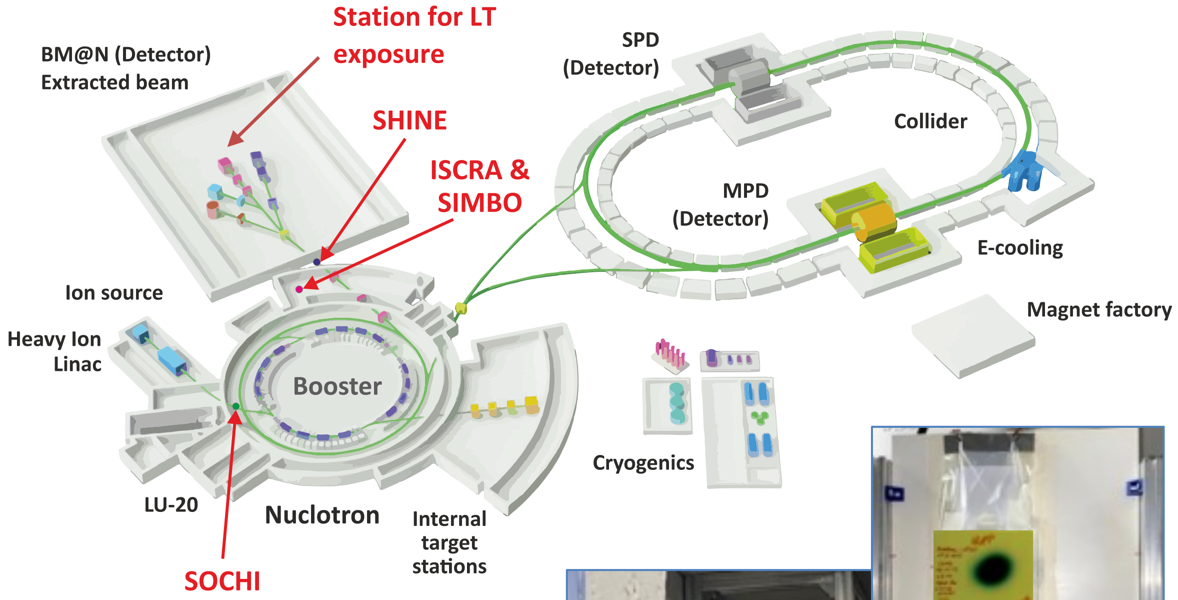
I. Infrastructure development

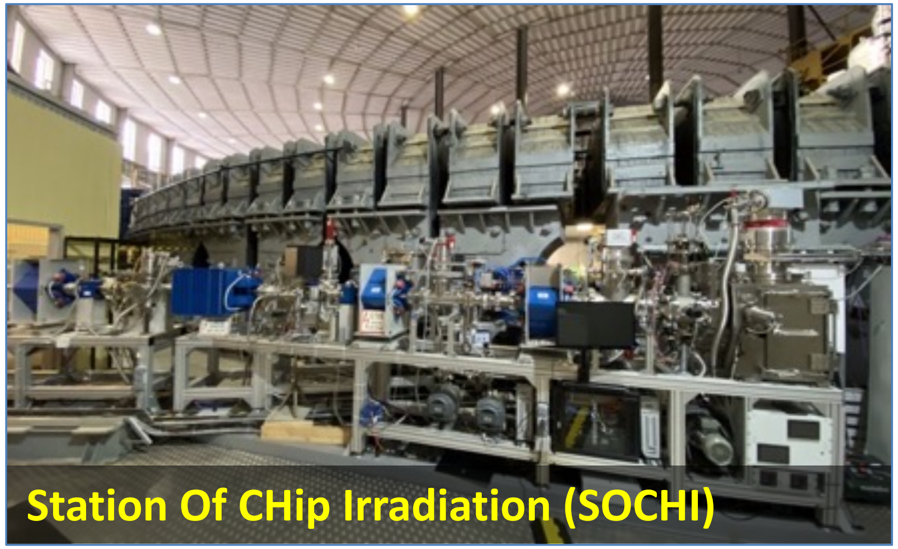
ARIADNA RESEARCH INFRASTRUCTURE: CURRENT STATE AND RECENT DEVELOPMENTS

In December 2021, the beamline and **Station Of CHip Irradiation (SOCHI)** was completed.

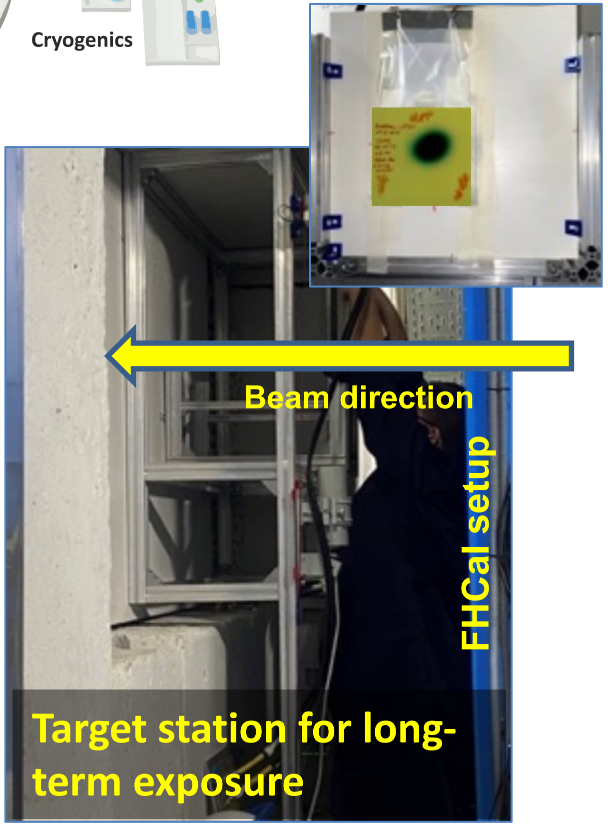
In December 2022, the **prototype of the Target station for long-term exposure with high energy ions** was assembled at the outgoing beam available behind the BM@N facility. This target station has an advantage to use beams for applied research purposes in parallel with operation of the BM@N setup.

The infrastructure of **SIMBO** and **ISCRA** beamline zones are close to completed (beamlines are still in progress).




Station Of CHip Irradiation (SOCHI)


SIMBO and ISCRA target stations



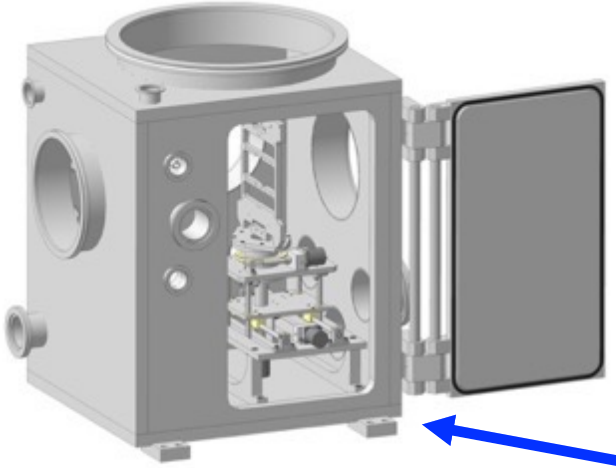
Target station for long-term exposure

LOW-ENERGY TARGET STATION FOR TESTING OF DECAPSULATED MICROELECTRONIC COMPONENTS

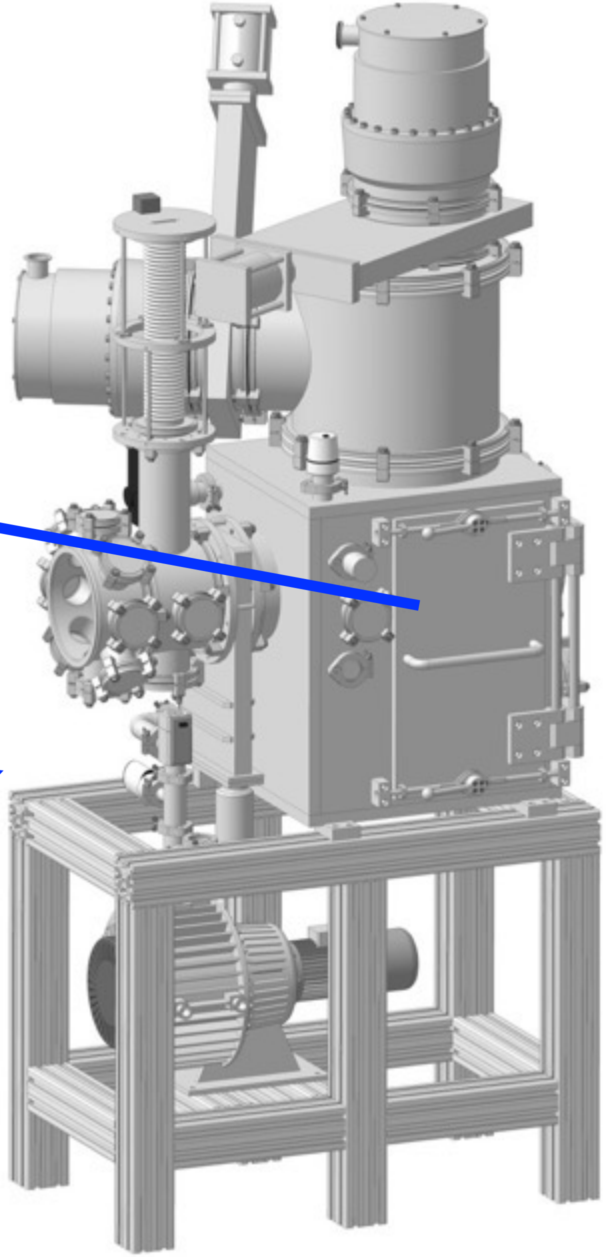
Low-energy beams extracted from the HILAC at energy 3.2 MeV/n.

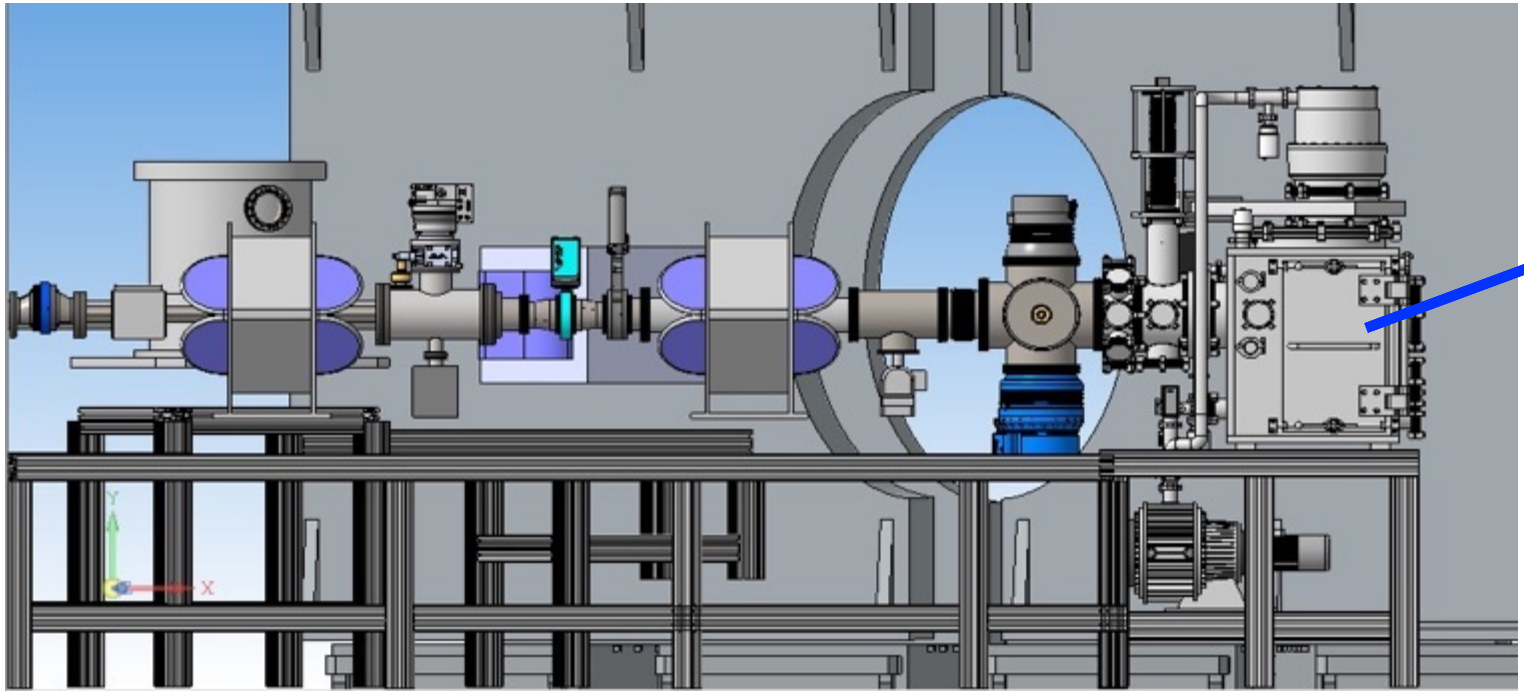
Protons and ions Z = 2 to 92.

The beamlines ands with a vacuum chamber designed for placement and online diagnostics of the microelectronic components' state.



Vacuum chamber

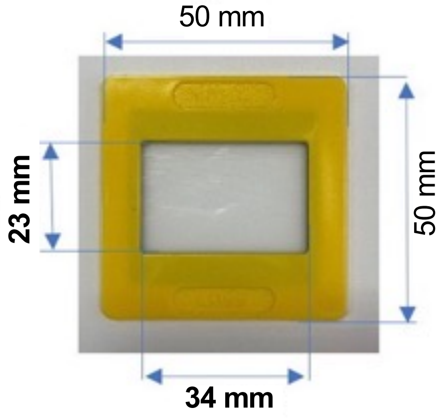




E. Syresin et al.

SOCHI FACILITY: TEST EXPERIMENT WITH IRRADIATION OF TRM-PTFE FILMS

TRM-PTFE films of 20 and 100 μm



Formula: $(C_2F4)_n$

Density TRM-PTFE: 2.20 g/cm^3

Irradiation area at the film: 23 x 34 mm

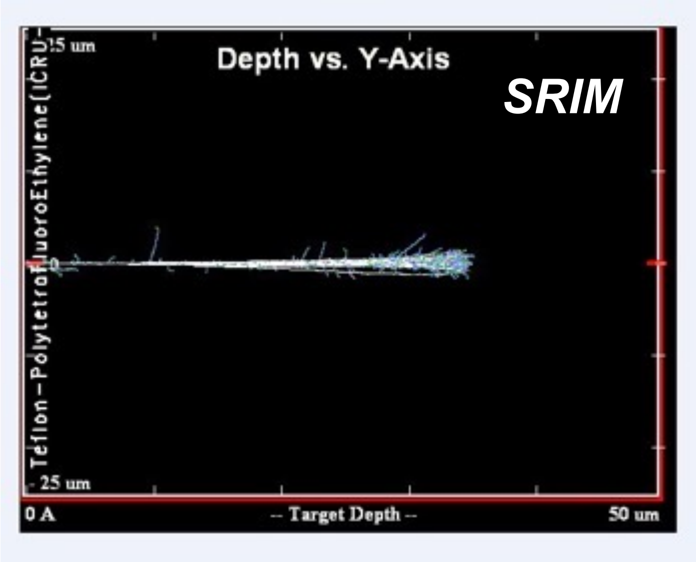
EXPOSURE TO 3,2 MEV/NUCLEON $^{124}Xe^{54+}$ IONS

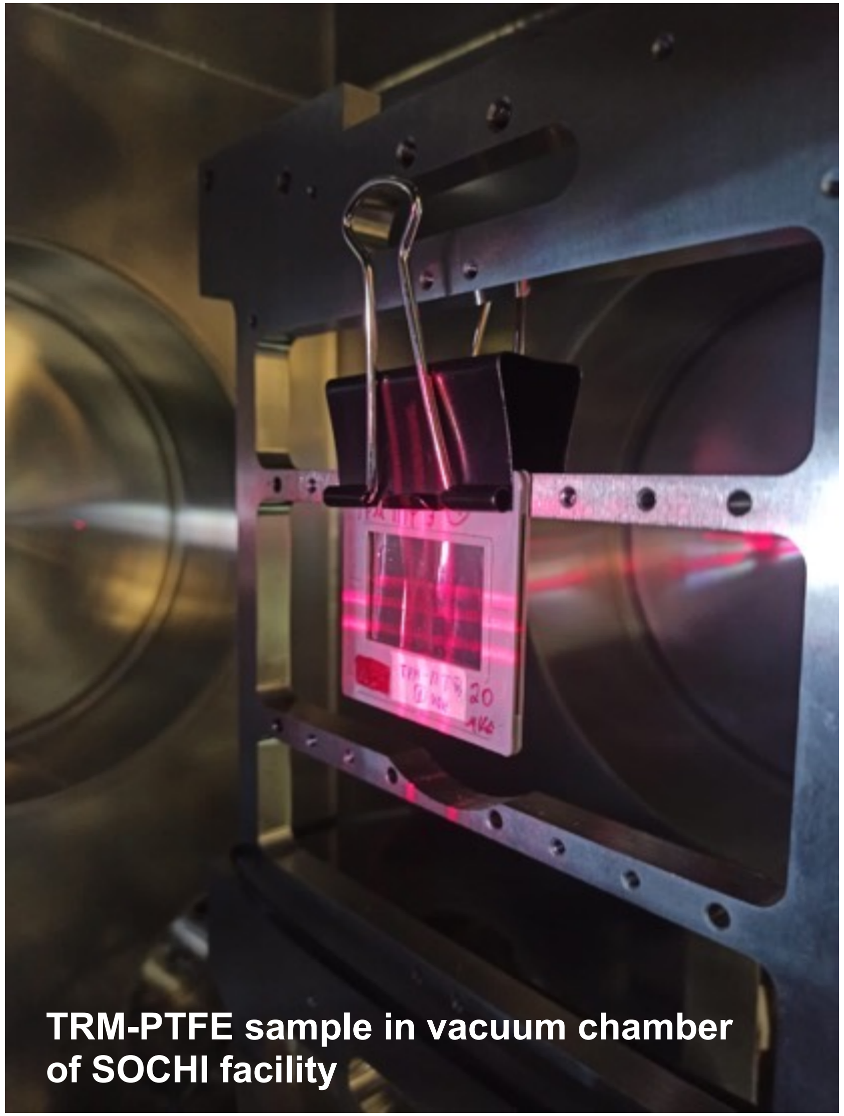
Irradiation in a vacuum chamber

Sample # 1 (20 μm): Φ = 1.08 x 10^6 particles/cm^2

Sample # 2 (20 μm): Φ = 1.12 x 10^5 particles/cm^2

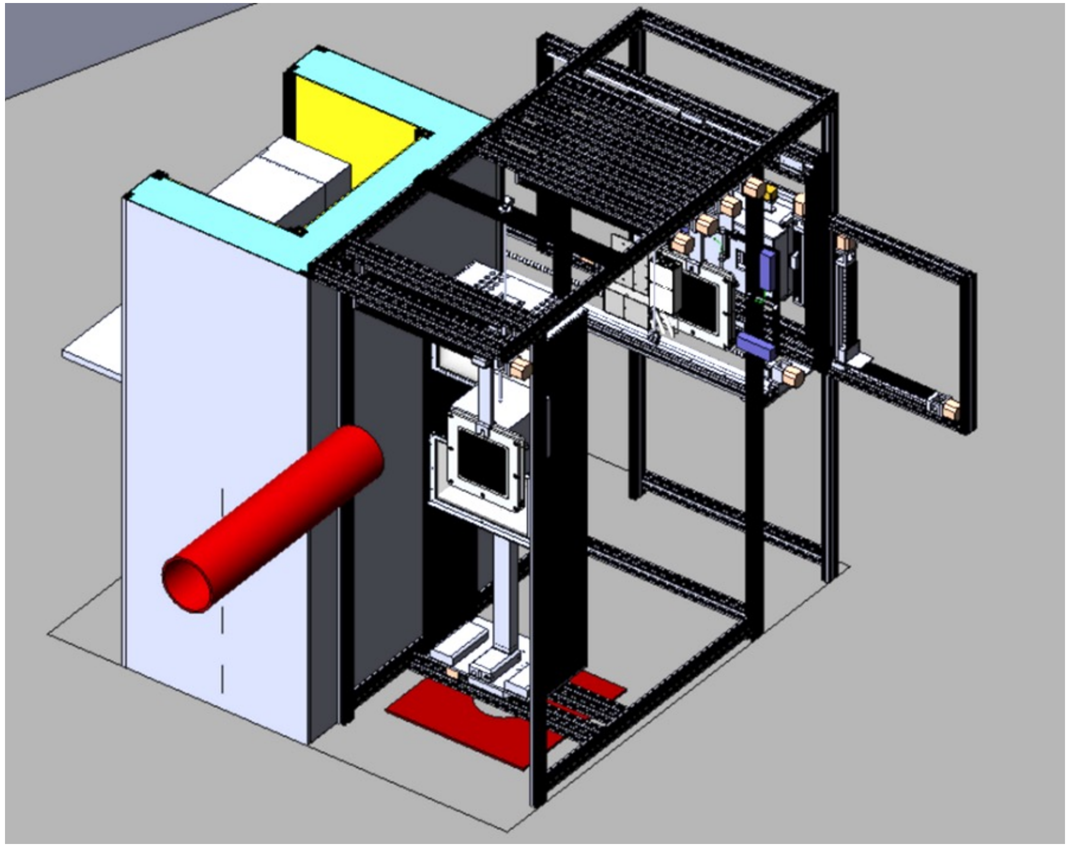
Sample # 3 (100 μm): Φ = 1.08 x 10^6 particles/cm^2




TRM-PTFE sample in vacuum chamber of SOCHI facility

TARGET STATION FOR TESTING OF CAPSULATED MICROELECTRONIC COMPONENTS (ISCRA)

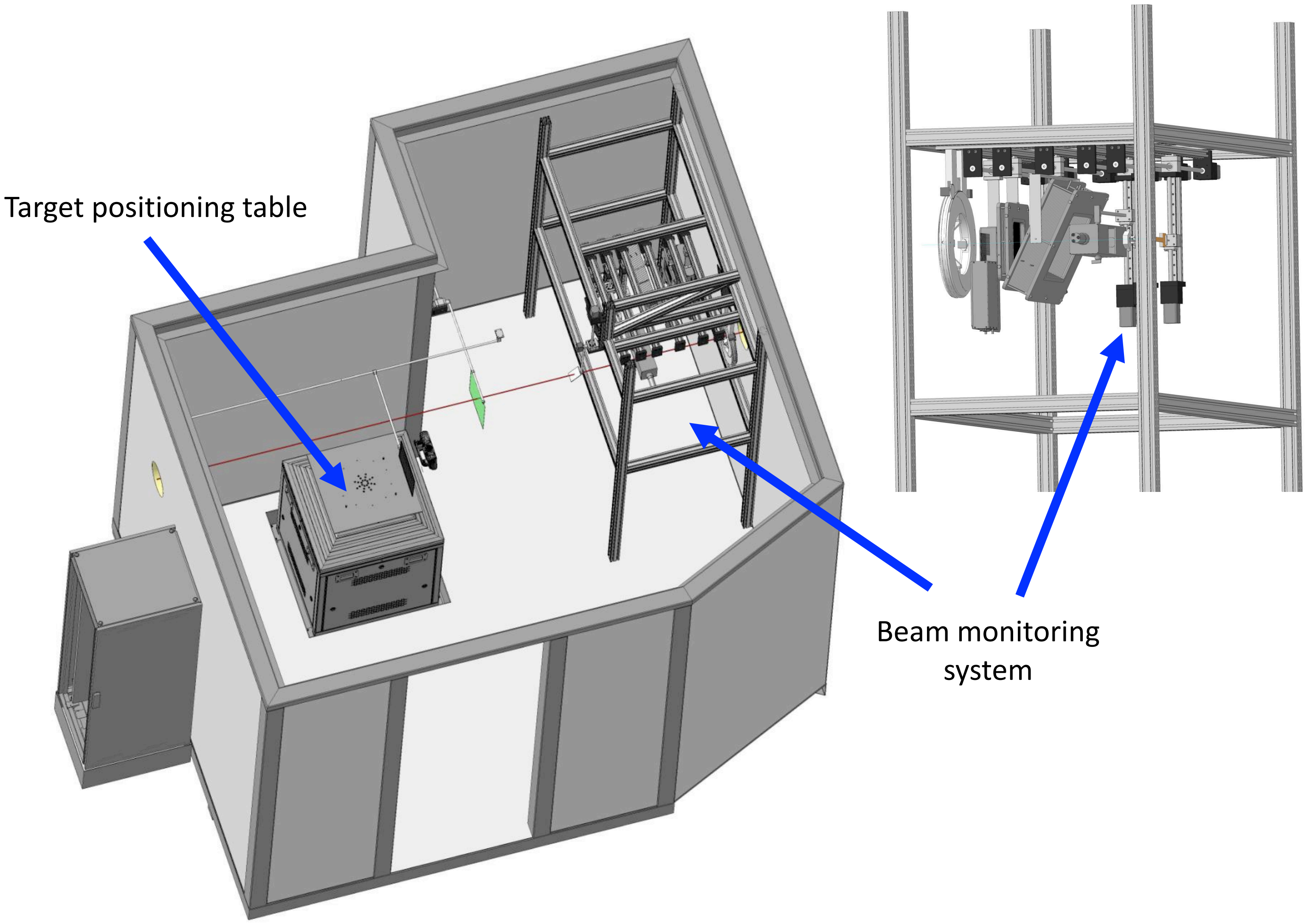
The beam diagnostic provides measurements of ion beam profiles, primary ion fluence, the primary ion density flux, the secondary particle density flux, the radiation dose: (three ionization chambers, scintillation-fiber detector, semiconductor detector, multi electrode cylinder Faraday, Si strip detector for individual ion detection, four on-line control scintillation detectors)



Beam parameters	
Ion types	$^{12}C^{6+}$, $^{40}Ar^{18+}$, $^{56}Fe^{26+}$, $^{84}Kr^{36+}$, $^{131}Xe^{54+}$, $^{197}Au^{79}$
Ion energy, MeV/n	150-350
Ion flux density, particle/(cm²·s)	10^2 .. 1×10^5
Fluence per session, ion/(cm²)	10^7
Area of chip irradiation of 20×20 mm without scanning, mm	∅30
Flow uniformity at chip irradiation of 20×20 mm without scanning	10%
Exposure area in scan mode, mm	200×200
Flux uniformity at scan irradiation	±15%
FWHM beam diameter at target, mm	25-73
Range of LET (Si)	1…70 MeV·cm²/mg

E. Syresin et al.

TARGET STATION FOR BIOLOGICAL OBJECTS (SIMBO)



Beam parameters

Ion types	$^{12}C^{6+}$, $^{40}Ar^{18+}$, $^{56}Fe^{26+}$, $^{84}Kr^{36+}$
Ion energy at the exit from the Nuclotron, MeV/n	500-1000
Ion flux density, particles/(cm²·s)	$10^3..10^6$
Irradiation time per run, min	1-5
Radiation dose, Gy	1-3
Maximum irradiation area in the scanning mode/ nonscanning mode, mm	100x100/Ø10
Flux uniformity for the maximum irradiation area in the scanning mode/ nonscanning mode, %	5/10
Beam FWHM at the target, mm	25-35

The target station is located inside an artificial climate box

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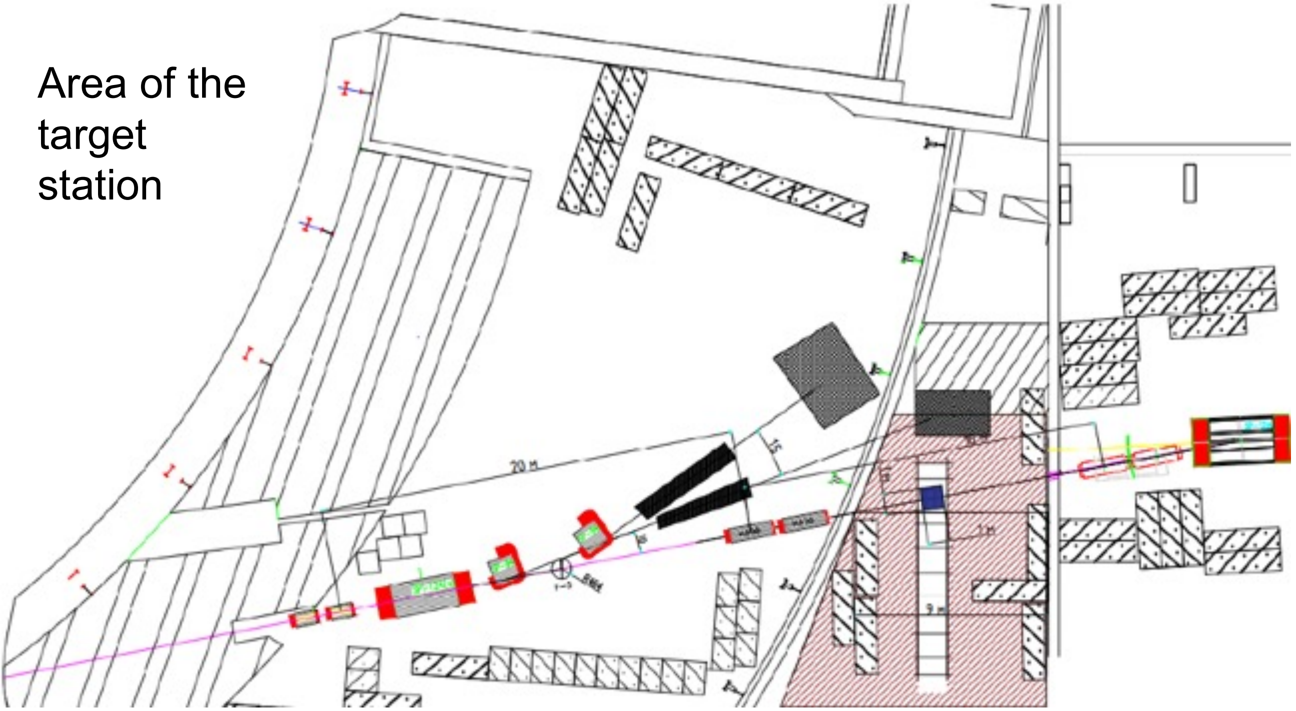
TARGET STATION FOR ADS AND RELATED APPLICATIONS (SHINE)

Area of the target station



Beam parameters

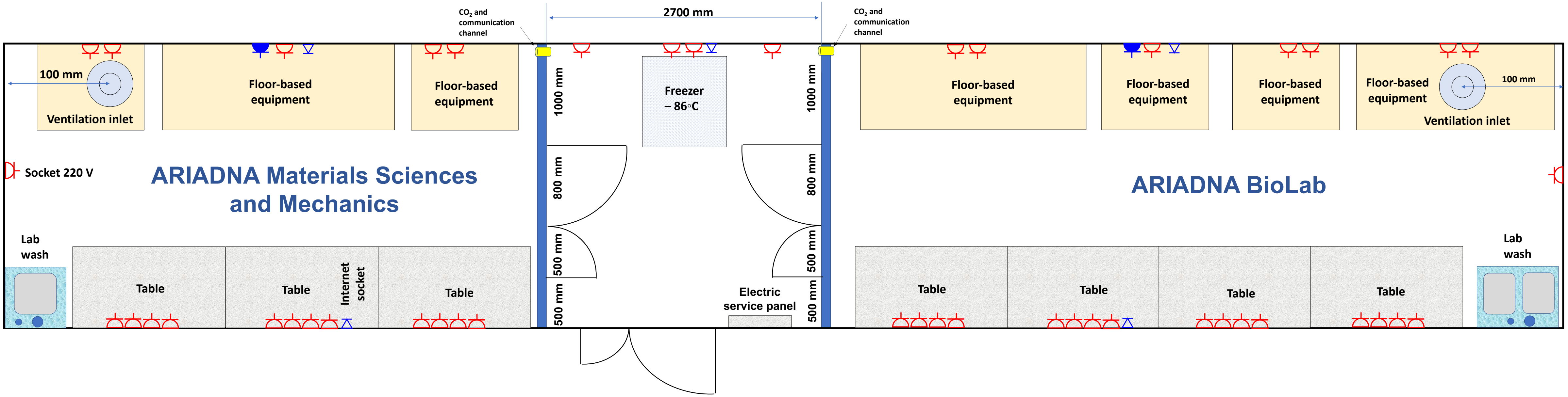
Ions	**$^{12}C^{6+}$, $^{40}Ar^{18+}$, $^{7}Li^{3+}$,$^{1}p^{1+}$, $^{2}D^{1+}$**
Ion energy, GeV/n	**0.3-4.0**
Ion intensity, 1/s	**$^{1}P^{1+}$, $^{2}D^{1+}$ - 10^{10} $^{12}C^{6+}$, $^{7}Li^{3+}$ - 10^{9}**
Nuclear impurities with non goal Z, %	**5**
Field of irradiation, mm	**∅ 20-50**
Fluence at irradiation of a single object	**>10^{14}**

The target station is developed for nuclear applications and ADSR. Light ion beams are planned to be used for the corresponding research program. Light ions have a short path in the target, which reduces the probability of inelastic nuclear interactions and the required beam power for ADS.

Equipment of the target station involves: targets from C up Pb at length up 1.5 m and diameter up 35 cm, thin targets from Be to U at thickness 0.05-50 mm; beam diagnostic system; target diagnostic system on base of activation and track analysis; target position system; thermometry system; synchronization system; radiation control system; data acquisition system.

The beams at this target station are also available for other directions of applied research

Development of User Infrastructure for applied research at NICA: Laboratory rooms for sample preparation and analyses



Biological Safety Cabinet, class II A2 w-1800 mm
Water purification system type I, 1.5 l/min
Bi-distiller, 8 l/h
Deep freezer, -86 °C
Laboratory freezer, +2…+15/-10…-25 °C
Muffle furnace up to 1100 °C, 10 l,
3D printer 40x40x45

Multi-gas incubator
Centrifuge up to 17500 rpm, 30130 g, with cooling
Thermostat
Dry-air sterilizer 80 l, up to 200 °C, forced ventilation
Analytical scales series 0.01 mg
pH meter, -2-20±0.001, stationary, electrode ST410
Laboratory water bath

IBMP Special-Purpose Laboratory for Space Research @ NICA: Ground-based experiments with ion beams

Being a member of ARIADNA Collaboration, The Institute of Biomedical Problems of RAS develops a special-purpose laboratory for Space Research at JINR, which is based on the previously existing building belonging to IBMP.

A complementary research programme between NICA and IBMP is concentrated of problems radiation research and radiation protection is space. It implies ground-based experiments at NICA ion beams.

A core facility for the IBMP-NICA space research programme is the Building # 123 located at the DLNP site of JINR. The IBMP funded the complete renovation and equipping this laboratory with analytical instruments. The renovation was started in June 2023 and planned to be completed by January 2025.

<u>Similar experience:</u>

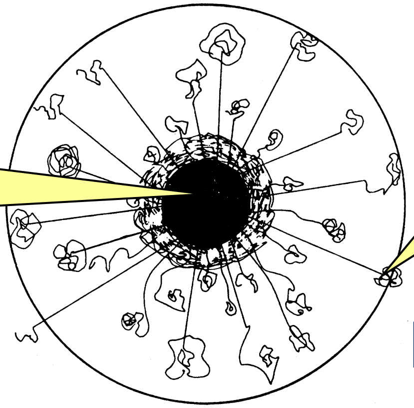
Special-purpose laboratories in the field of applied research are efficient models of interaction between large accelerator facilities with space research organizations. NASA space agency organized a dedicated NSRL facility at Brookhaven National Laboratory (USA) operating in a similar way for many years.

II. Research activities and selected results

STRUCTURE OF AN ION TRACK

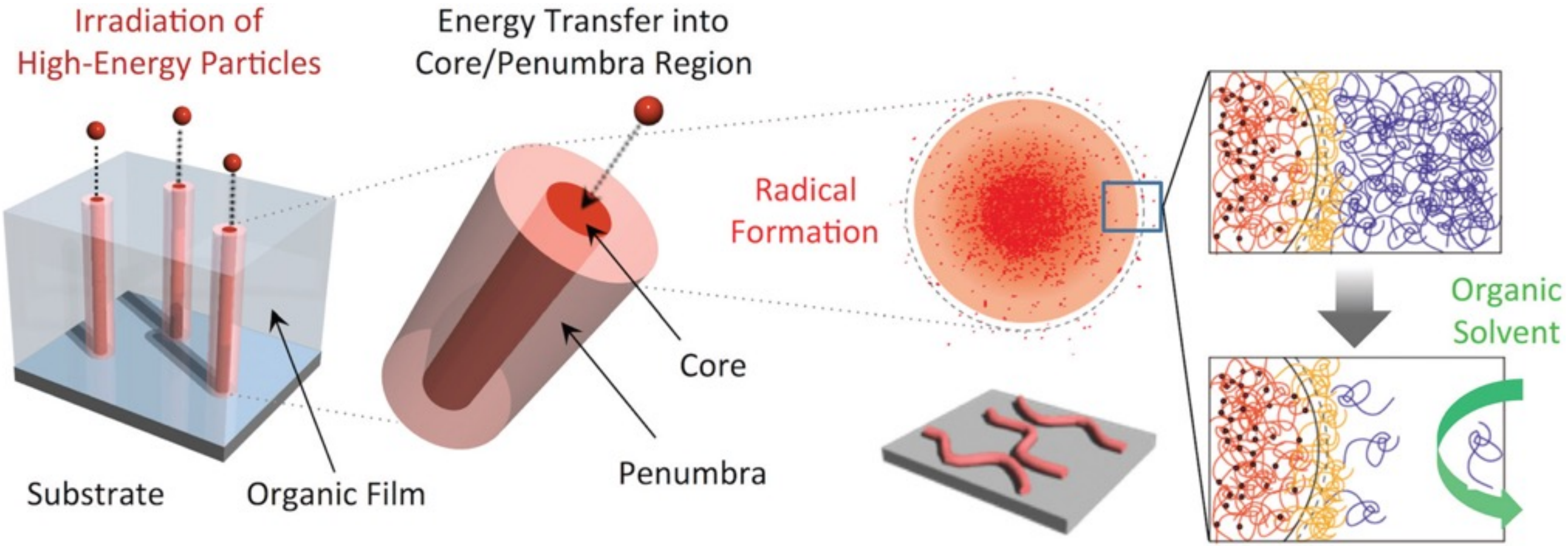
Track core
Diameter ≤ 10 nm

Track halo
Diameter up to ~ 100 nm



(after Chatterjee and Magee (1980))

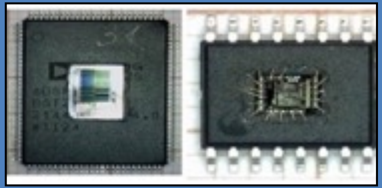
Radial projection



Modified from
Horio A. et al.
Nanoscale.
2016 8(32)

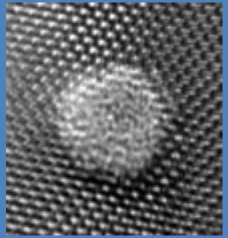
PILLARS OF APPLIED RESEARCH WITH NICA BEAMS

Radiation effects in microelectronics

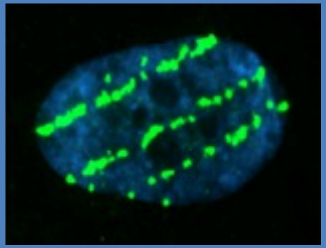


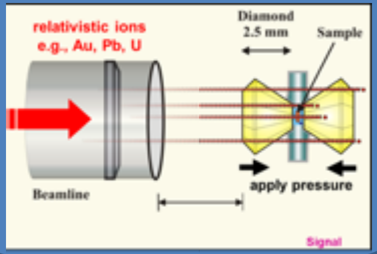
Radiation protection on Earth and in space

Materials research with ion beams

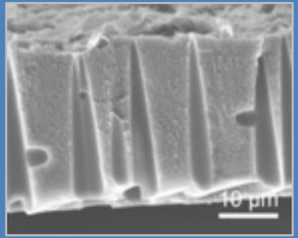


Radiation biophysics and radiobiology

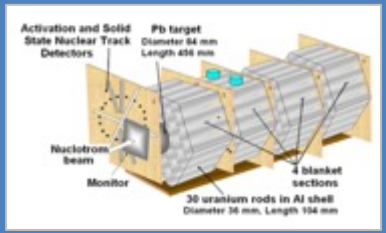




Materials in extreme radiation dose conditions



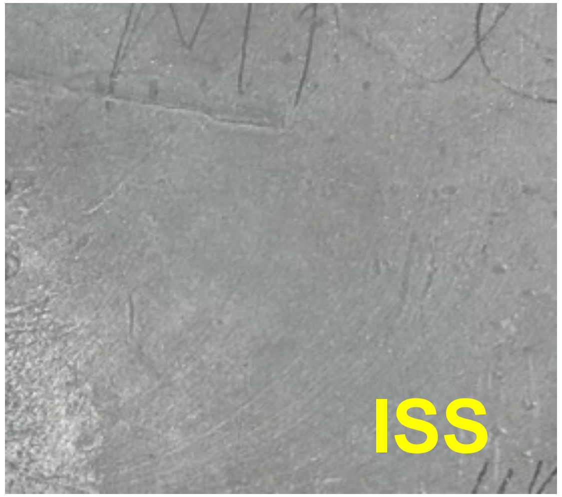
Radiation therapy-related research



Novel technologies for accelerator-driven systems (ADS)

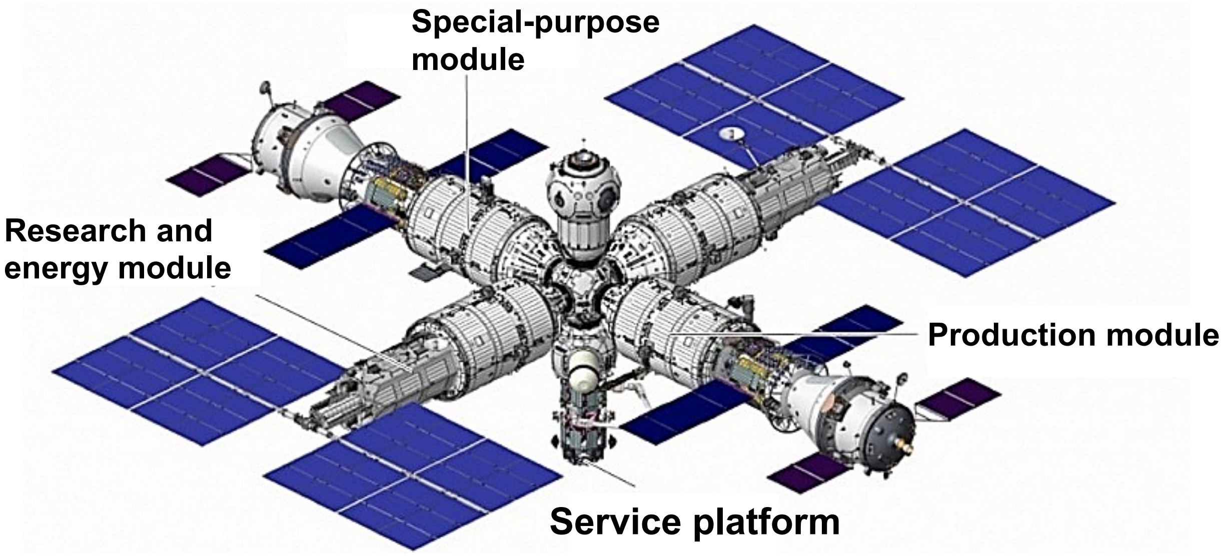
Space Research work package: New composite materials for space industry (protective properties, radiation resistance, radiation-induced modification)

- Improving the regular means of radiation protection in spacecrafts for orbital flights and missions beyond the Earth magnetosphere.
- Study of shielding properties of existing and new composite materials.
- Investigation of radiation modification of composite materials by high-energy accelerated ion beams during long-term irradiation.

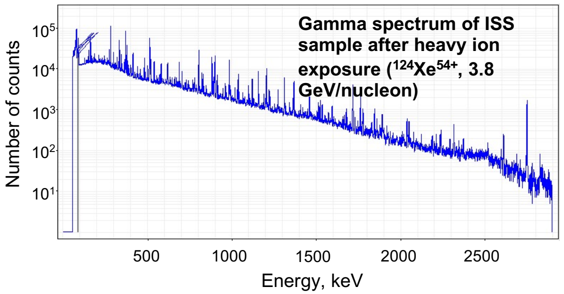


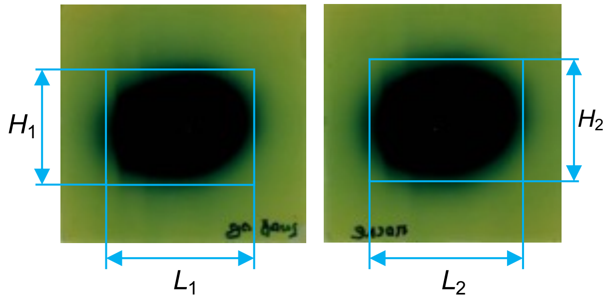
Shielding material from the International Space Station (ISS)

New shielding material for the future Russian Orbital Service Station (ROSS)



Project of the new Russian Orbital Service Station (ROSS)





- ❑ Structural, chemico-physical methods of research and testing.
- ❑ Comparative studies under the influence of other types of ionizing radiation.

Radiation testing of electronics with ions of relatively high energy

Two types of radiation effects

- Cumulative (dose) effects result from long-term exposure to radiation environment
- Single-Event Effects (SEE) occur promptly due to a **single particle** strike

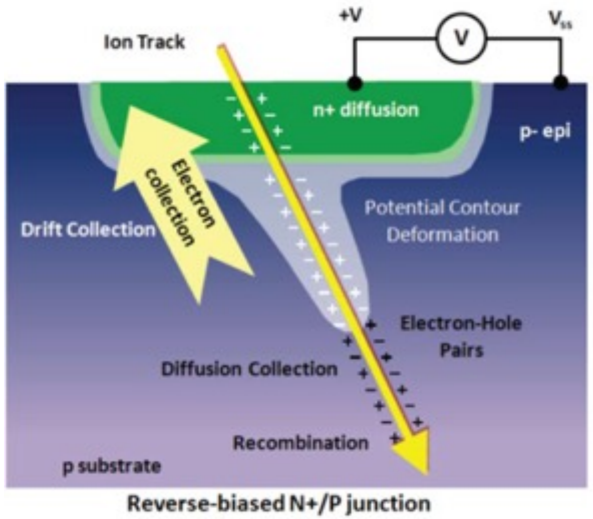
Recent studies: 25-50% of spacecraft anomalies due to SEE (depends on spacecraft orbits)

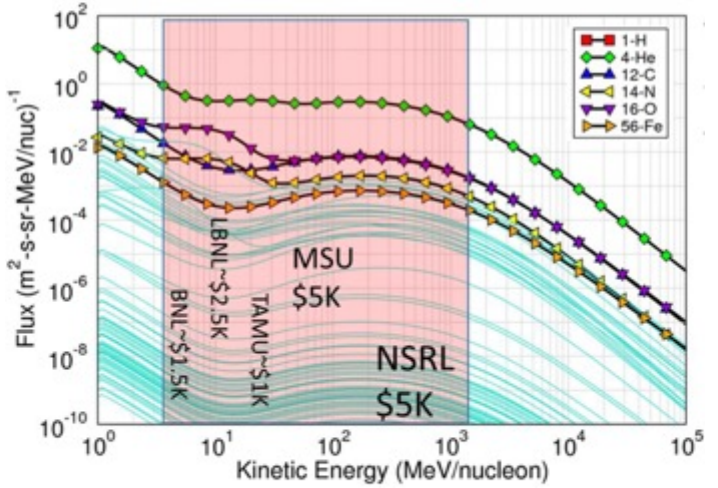
Increasing integration poses problems for SEE testing with low-energy beams

- Multiple die stacked together in packages.
- Behavior may differs if dis-assembled, tested separately.
- Packages now intrinsic to part performance.
- Dis-assembly may compromise timing, thermal and structural characteristics—especially if thinning required.

SEE Frontiers:

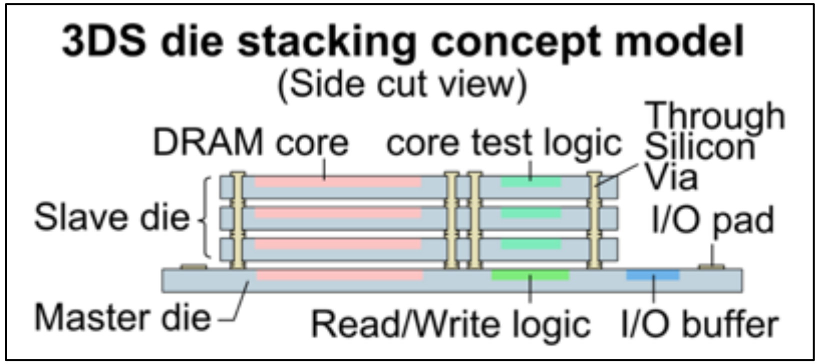
1. Technology Frontier
2. Low-Energy Frontier
3. **High-Energy Frontier – relevant to facilities like NICA**

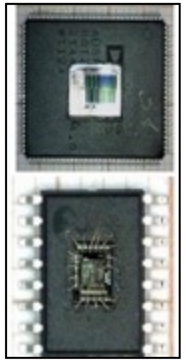




/R.C. Baumann, 2013 NSREC Short Course/

- Ideally, prefer test with ions' characteristic relevant to space
- GCR ions fairly flat out to >2 GeV/nucleon (min. ionizing)
- Difficult and expensive to achieve at accelerators





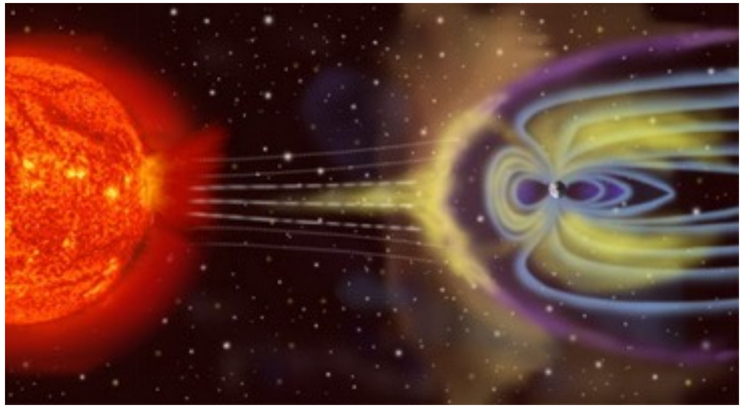
/By R.L. Ladbury at the Meeting of the American Physical Society, Columbus, OH, April 14-17, 2018/

RISK ASSESSMENT IN LONG-TERM MANNED SPACE MISSIONS

- Carcinogenesis. Increased risk of sickness or death from cancer.
- Assessment of the risk of prolonged outcomes due to the central nervous system (CNS) inmairement, incl. changes in motor functions, operator activity, behavior, memory and appearance of neurological disorders.
- Assessment of the risk of tissue degeneration (non-malignant and not related to the central nervous system).
- Radiation as a risk factor for diseases associated with the functions of the heart, cardiovascular and digestive systems, as well as the induction of cataracts.
- Combined influence of radiation and other factors of space flight.

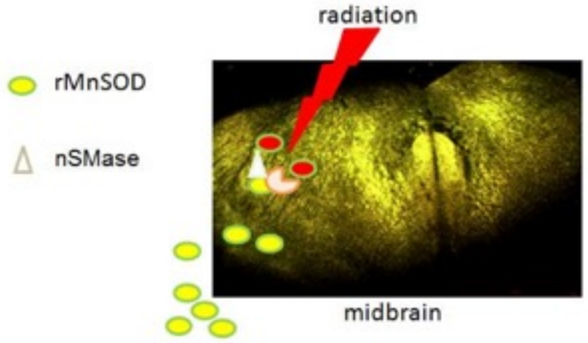
etc. …

Implementation of the research program in collaboration with organizations responsible for the medical care of astronauts during current manned flights and future interplanetary missions

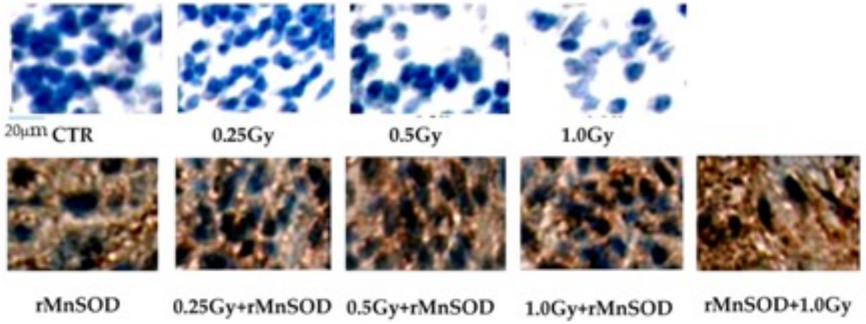


Radiation safety and radiation protection frontiers: Biomedical measures

Development and testing of pharmaceuticals for protecting astronauts from space radiation on experimental models of laboratory animals



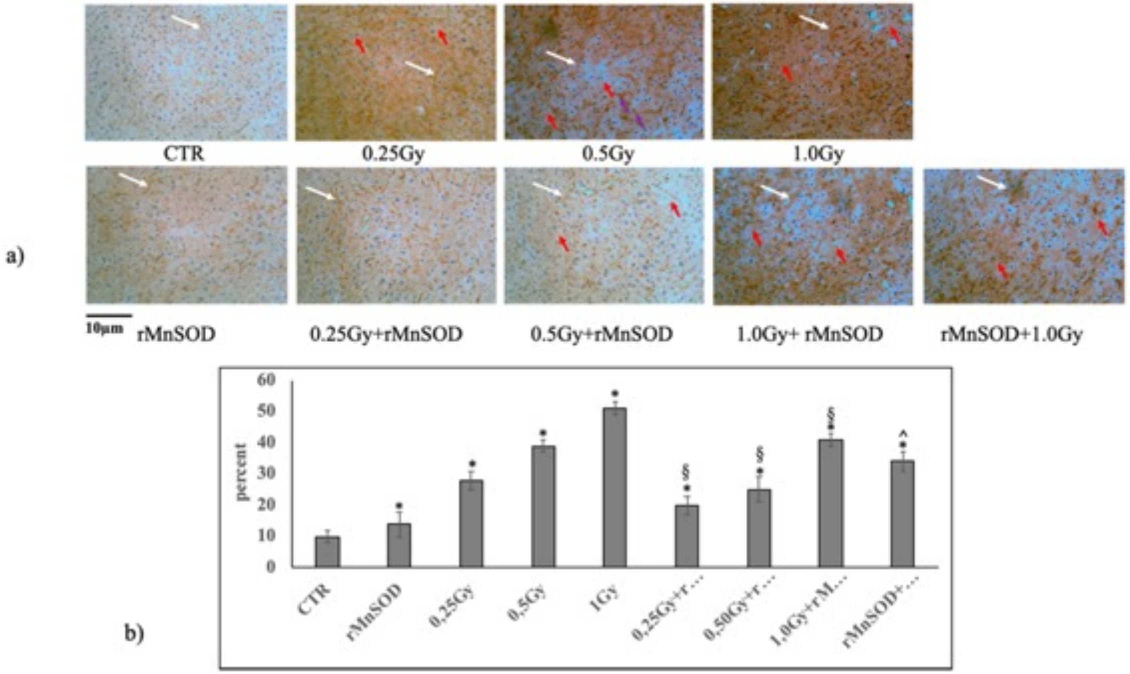
It has been established that recombinant human manganese-containing superoxide dismutase (rMnSOD), which has specific antioxidant and antiradical activity, is able to overcome the blood-brain barrier and penetrate into the midbrain, preventing radiation damage.



Localization of rMnSOD in brain tissue. Immunohistochemical analysis was performed by using specific antibody. The immunostaining was evident only in brain samples from rMnSOD-treated mice.

Cataldi, S.; Borrelli, A.; Ceccarini, M.R.; Nakashidze, I.; Codini, M.; Belov, O.; Ivanov, A., et al. Neutral Sphingomyelinase Modulation in the Protective/Preventive Role of rMnSOD from Radiation-Induced Damage in the Brain. Int. J. Mol. Sci. 2019, 20, 5431.

The ability of rMnSOD to reduce radiation-induced damage has been shown, both through a protective role associated with sphingomyelinase with an acidic pH optimum (aSMase), and through a prophylactic role through sphingomyelinase with a neutral pH optimum (nSMase).



Mouse liver after irradiation with or without protective or preventive rMnSOD treatment (**a**) representative liver histology by Caspase-1 immunohistochemical staining. (**b**) Quantification of Caspase-1 staining was performed using the ImageFocus software. Positive staining is indicated as low (+), medium (++), or high (+++). Only high positive staining was considered and was measured as a percentage of the total area. Data represent the mean + S.D. of three livers for each group. Significance, * $p < 0.05$ with respect to the CTR, § $p < 0.05$ with respect to the irradiated samples, ^ $p < 0.05$ with respect to 1.0 Gy + rMnSOD.

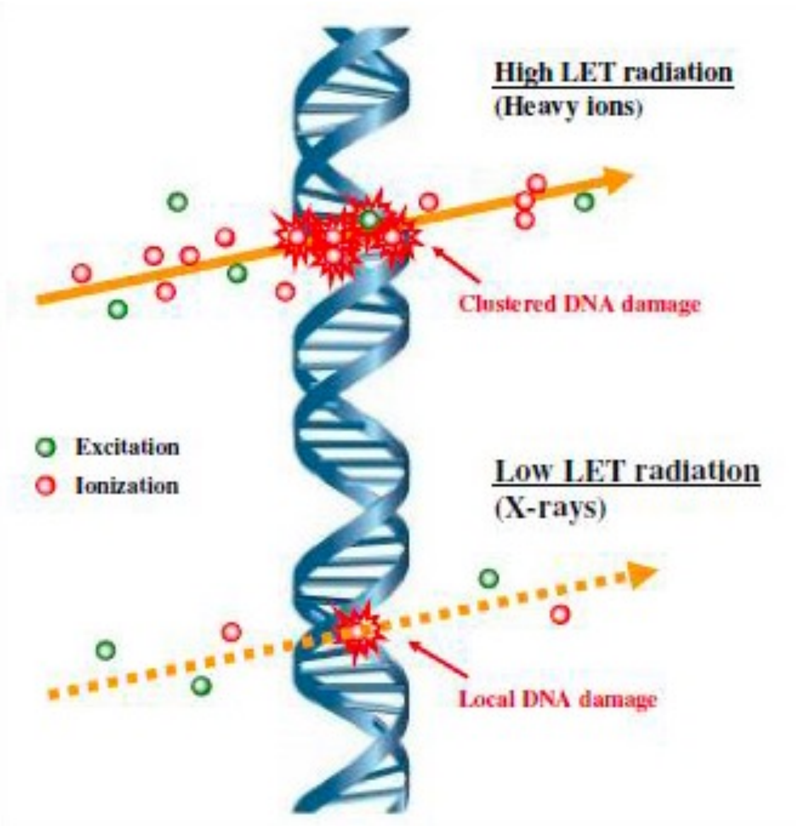
Cataldi S, Borrelli A, Ceccarini MR, Nakashidze I, Codini M, Belov O, Ivanov A, et al. Acid and Neutral Sphingomyelinase Behavior in Radiation-Induced Liver Pyroptosis and in the Protective/Preventive Role of rMnSOD. Int J Mol Sci. 2020, 21(9), 3281.

DNA REPAIR PROTEIN MARKERS FOR CANCER CHARACTERIZATION

Studying the mechanisms and regularities of DNA repair in normal and cancer cells exposed to different types of radiation exposure (including ion beams produced by NICA facility) enables to identify specific protein markers associated with cancer.

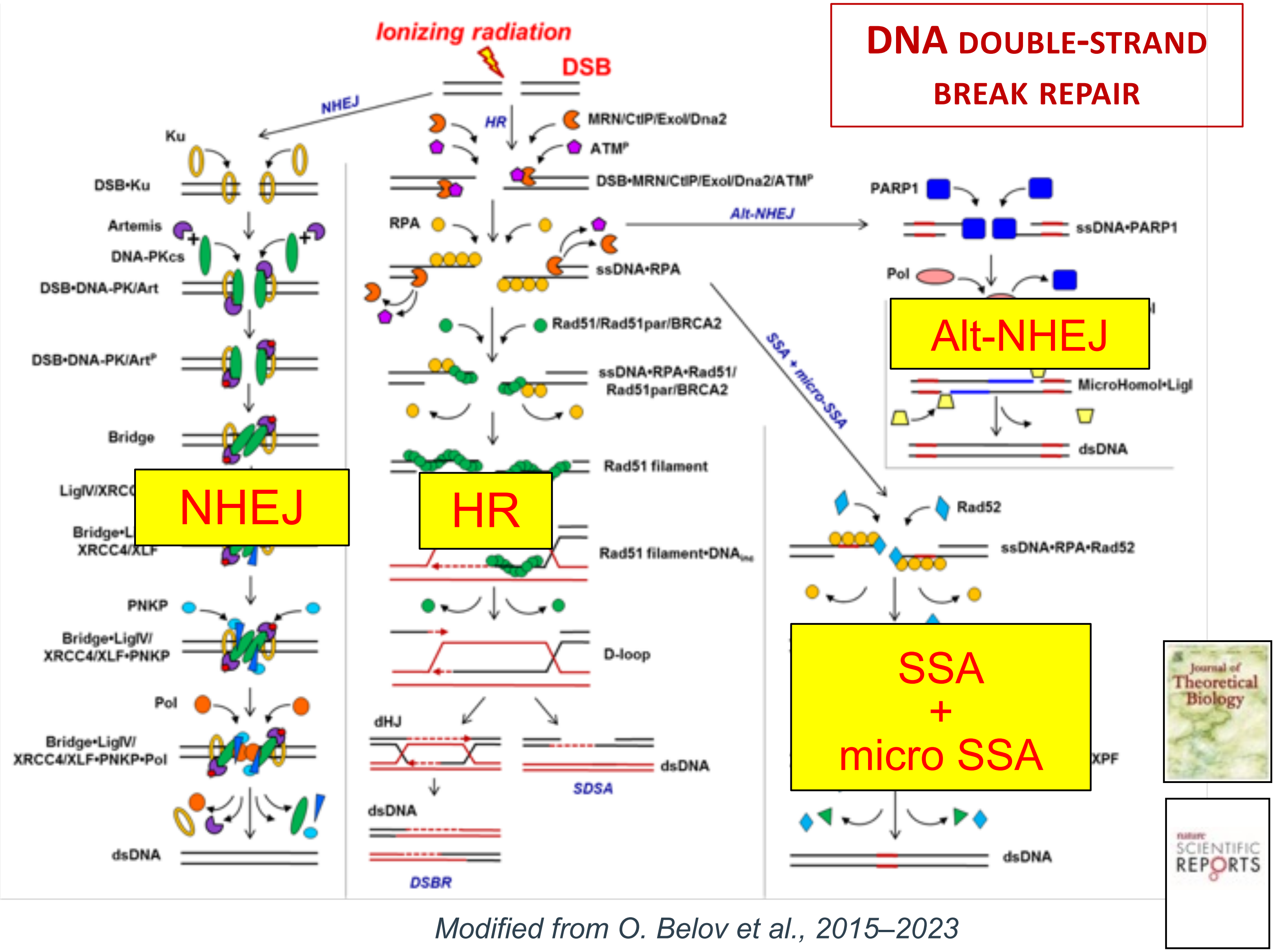
JOINT PROJECT WITH INSTITUTO NACIONAL DE CANCEROLOGÍA (INCAN, MEXICO)

RADIATION-INDUCED DNA DAMAGE



Modified from W. Tinganelli and M. Durante. Carbon Ion Radiobiology. Cancers 2020, 12, 3022

DNA DOUBLE-STRAND BREAK REPAIR

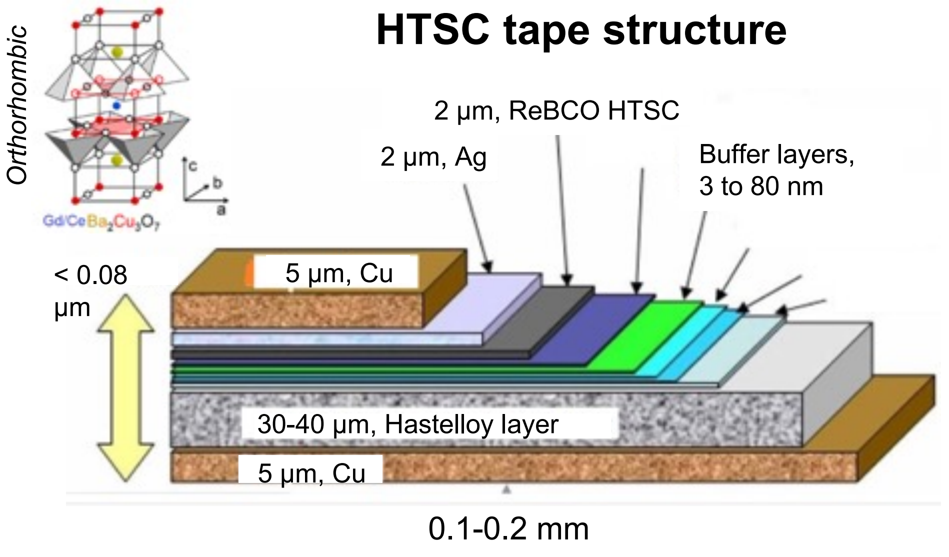


Modified from O. Belov et al., 2015–2023

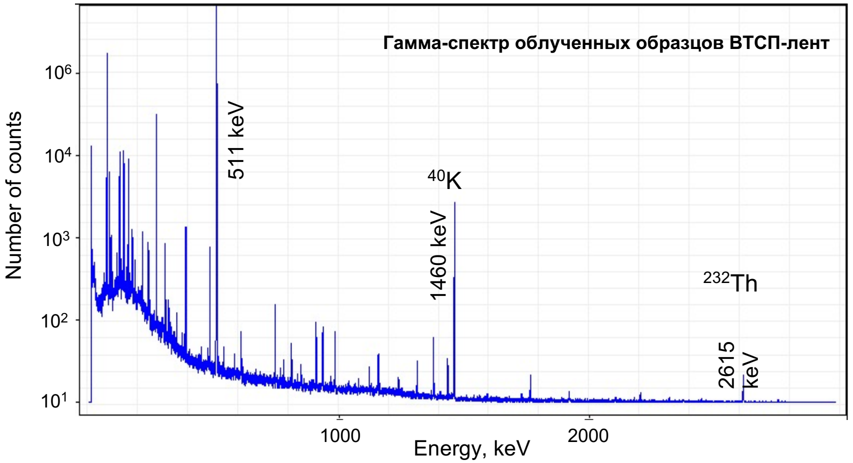
Materials Science working package: Irradiation of high-temperature superconducting tapes

- Development of methods for increasing the critical current of high-temperature superconductors (HTSC) by means of radiation modification (induction of pinning centers in the bulk of the superconductor).
- Comparative analysis of the critical current values upon irradiation of HTSC tapes with $^{124}Xe^{54+}$ ions of 3.8 GeV/nucleon and protons of 660 MeV.
- Estimation of the stability of the effect of increasing the critical current in an irradiated superconductor.
- Development of equipment prototypes based on radiation-modified HTSC tapes and their testing.

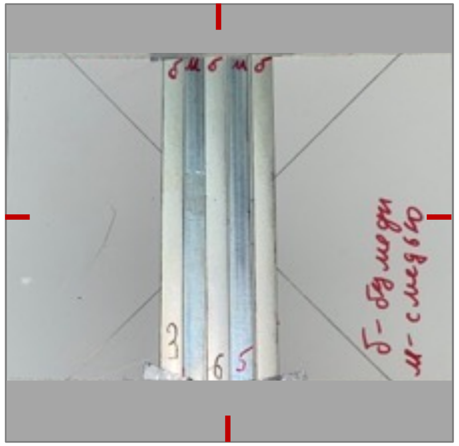
HTSC tape structure

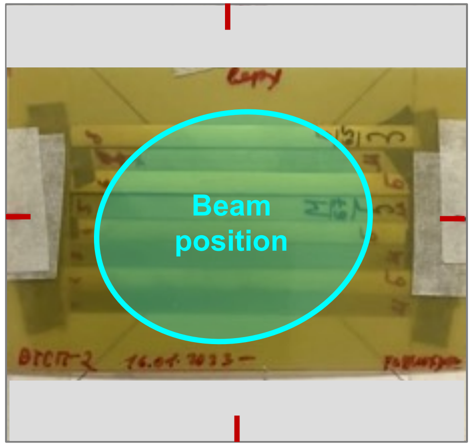


Methods for measuring current-voltage characteristics, Hall coefficient, magnetoresistance, thermo-EMF coefficient, thermal conductivity coefficient, magnetic moment in the temperature range of 1.7–300 K and magnetic fields up to 8 T.



Irradiation of vertically and horizontally arranged HTSC tapes with and without copper content

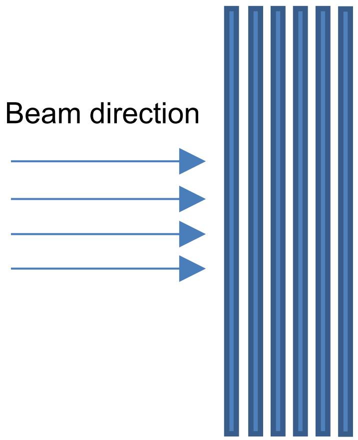


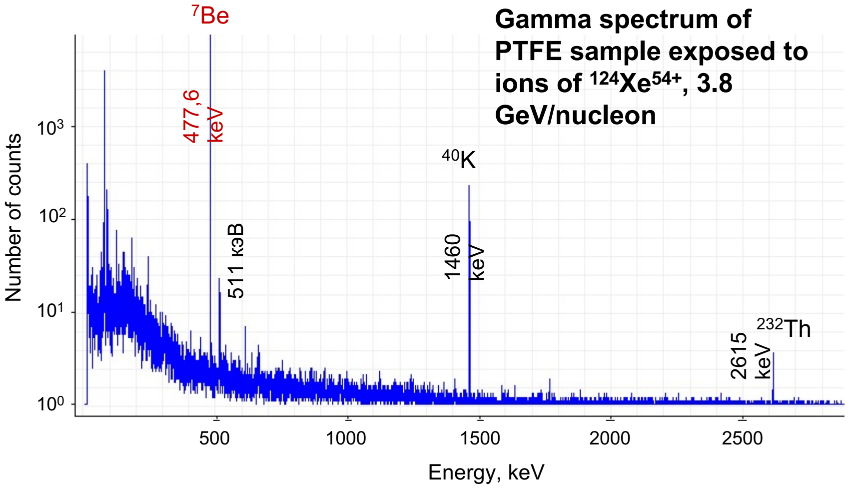


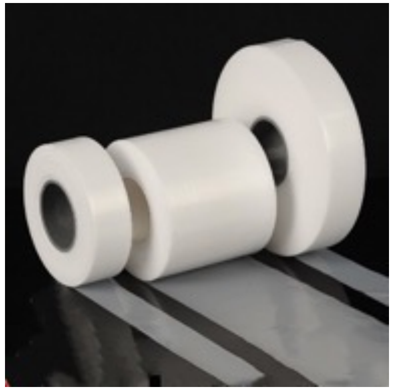
RADIATION MODIFICATION OF POLYTETRAFLUOROETHYLENE (PTFE), POLYETHYLENE TEREPHTHALATE (PET), POLYETHYLENE (PE) AND POLYIMIDE (PI) FILMS

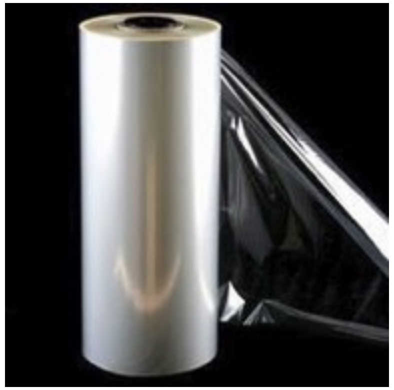
- Study of the processes of amorphization and recrystallization of polymers and nanocomposite materials.
- Investigation of regularities of radiation-chemical damages in PTFE, PET, PE and PI films.
- Establishment of regularities in radiolysis of condensed matter under the exposure to ion beams with energies of several GeV/nucleon.
- Development of ion-track technologies with "thick" targets and multilayer materials.

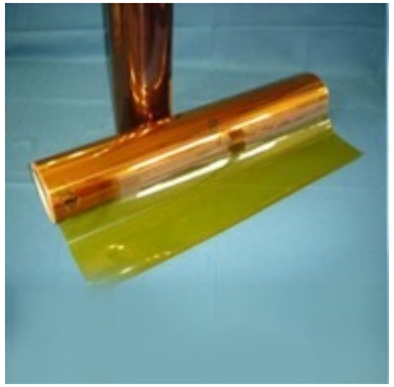
Multilayer film packs for exposure









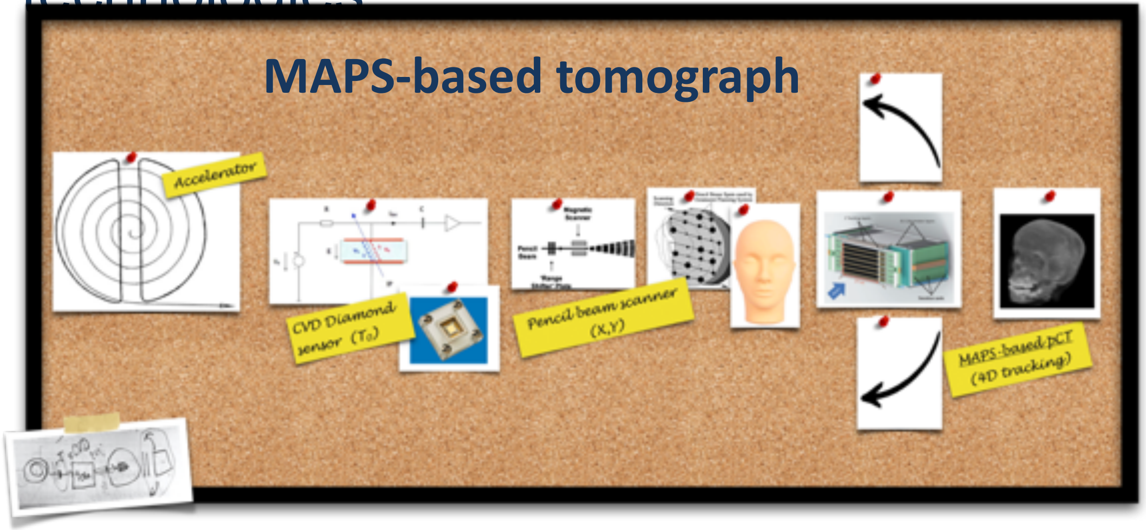


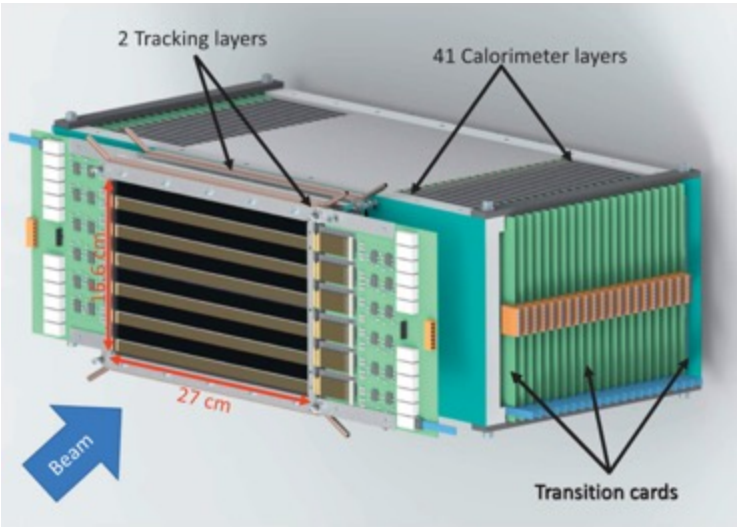
PTFE, PET, PE and PI films of 12, 20, 40, 50, 80 μm thick

Research methods: scanning and transmission electron microscopy, X-ray phase analysis, X-ray photoelectron spectroscopy and X-ray energy-dispersive elemental analysis, atomic force microscopy and low-temperature nitrogen sorption, wettability with respect to water and heptane, optical and infrared spectroscopy, infrared spectroscopy of frustrated total internal reflection, diffuse spectroscopy and specular reflection, laser Doppler strainmetry.

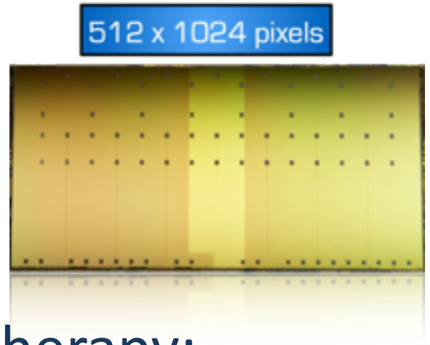
NICA DETECTOR TECHNOLOGIES FOR MEDICINE

NICA facility is a “zoo” of detectors. Some of them are essential for development of advanced tomography technologies



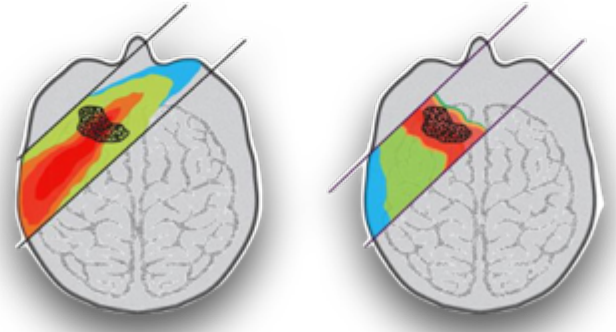


In total we would like to have 48 planes with 9 x 18 MAPS chips each for a total of about 7300 chips



MAPS = Monolithic Active Pixel Sensor

Photon Proton



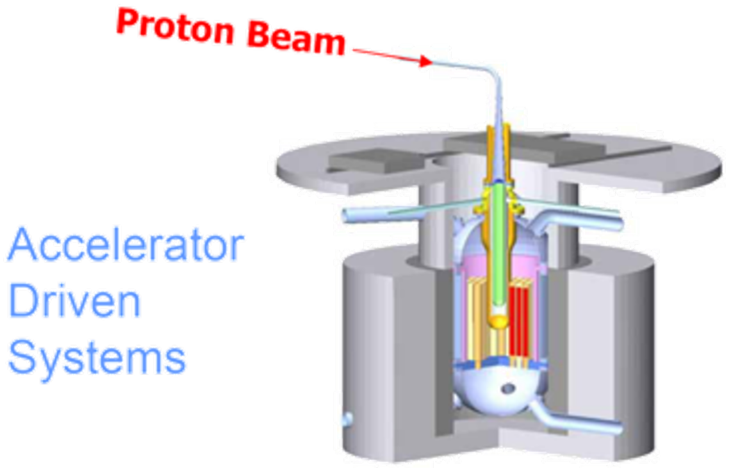
Improving the treatment planning for proton therapy: By ensuring diagnosis-therapy particle consistency the uncertainty ranges goes down to 0.3 - 1% versus ~7.4% with tomography practices used in present-day medicine

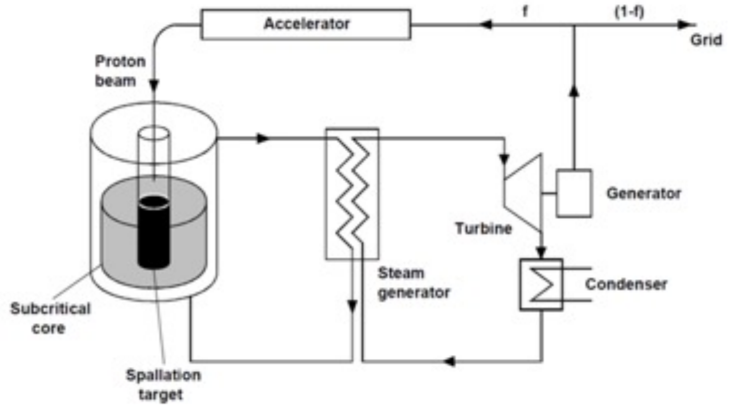
NOVEL NUCLEAR TECHNOLOGIES WITH NICA BEAMS

Accelerator Driven Systems (ADS) are the nuclear systems based on interaction of particle beams extracted from the accelerator with deeply subcritical quasy-infinite active zones consisting of the depleted (natural) uranium, thorium and spent nuclear fuel.

In previous years, the conditions which maximize the efficiency of ADSR were investigated. The optimal value of criticality coefficient of the core k_{eff} is in the range 0.985 - 0.988. It was suggested that the best choice for the converter is Be, especially for ion beams at low energy.

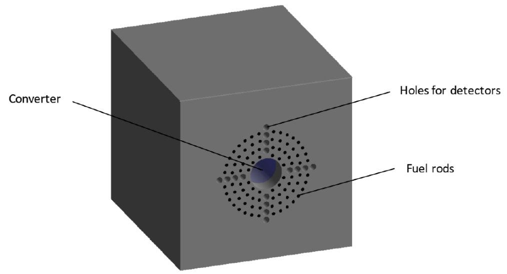
The maximum energy gain of protons is obtained at 1.5 GeV when they are accelerated in a LINAC, and at lower energy (0.75-1 GeV) when a cyclotron is used. In both situations ion beams starting with ^{4}He realize higher energy gain than protons. When particles are accelerated in a LINAC, at low accelerator length a beam of ^{7}Li with energy 0.25 AGeV represents the best option.





Within the next years the ADSR project will be concentrated on:

- **Research activities, involving simulation study, on an optimal design of the target;**
- **Verification of a principally new concept of a system based on the use of ion beams instead of protons;**
- **Implementation of the first stage of experimental program focused on measurement of the neutron yields with different converter combinations.**



III. Cooperation with ARIADNA: today and tomorrow

RECENT EVENTS AND DEVELOPMENTS

ARIADNA – Applied Research Infrastructure for Advanced Developments at NICA fAcility

ARIADNA COLLABORATION MEETINGS

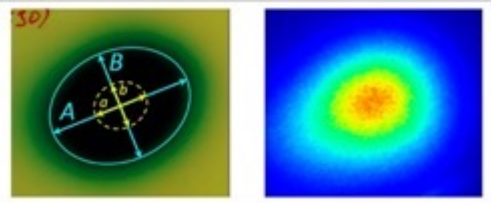
31 MAY 2024 **4-6 SEPTEMBER 2024**

Meetings were held in a hybrid form; each of them was attended more than 100 scientists from research centers of JINR Member States.

Meetings were focused on the **ARIADNA research programme,** which was presented by representatives of leading participating organizations, as well as on **implementation of grants** received as a governmental support for doing research at NICA.

DEVELOPMENT OF THE TARGET STATION PROVIDING UNIQUE OPTION OF LONG-TERM RADIATION EXPOSURE TO HIGH-ENERGY ION BEAMS

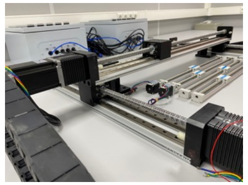
The target station is intended for use at the outgoing beam after the BM@N facility

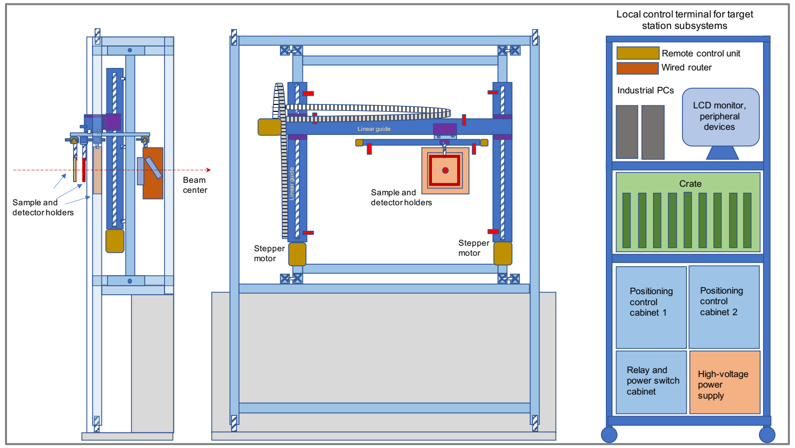


$^{124}Xe^{54+}$

3.8 GeV/n

The prototype of the target station was tested during the NICA Run within the period of 11 December 2022 – 30 January 2023





Method for manufacturing of a light reflector

First join patent within the ARIADNA collaboration activity (JINR, FRC CP RAS, FRC PCP MC RAS and MEPhI)

Thank you for your attention

Contact information:

Oleg Belov

Veksler and Baldin Laboratory of High Energy Physics,

Joint Institute for Nuclear Research

E-mail: oleg.belov@jinr.int