International Round Table on Applied Research and Innovations @ NICA

Research of radiation resistance of sensors, detectors and materials for NICA collider at irradiation facility of the IBR-2 reactor

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Organizations

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[2]**Veksler and Baldin Laboratory of High Energy Physics**, Joint Institute for Nuclear Research, Dubna, Russian Federation

[3]**Dzelepov Laboratory of Nuclei Problems**, Joint Institute for Nuclear Research, Dubna, Russian Federation

[4]**Flerov Laboratory of Nuclear Reactions**, Joint Institute for Nuclear Research, Dubna, Russian Federation

[5]**Magnetic Sensor Laboratory**, Lviv Polytechnic National University, Kiev, Ukraine

[6]**Glass and Ceramics Technology Department**, Belarusian State Technological University, Minsk, Belarus

[7]**Ural Federal University**, Yekaterinburg, Russian Federation

[8]**National Research Nuclear University MEPhi**, Moscow, Russian Federation

[9]**Institute of Nuclear Physics of Academy of Science of Uzbekistan**, Tashkent, Republic of Uzbekistan

[10]**Canada's particle accelerator center TRIUMF**, Vancouver, Canada

[11]**P.N. Lebedev Physical Institute of the Russian Academy of Sciences**, Moscow, Russia

[12]**Department of Physics of Nanjing University**, Nanjing, China

[13]**European Spallation Source**, Neutron Chopper Group, Lund, Sweden

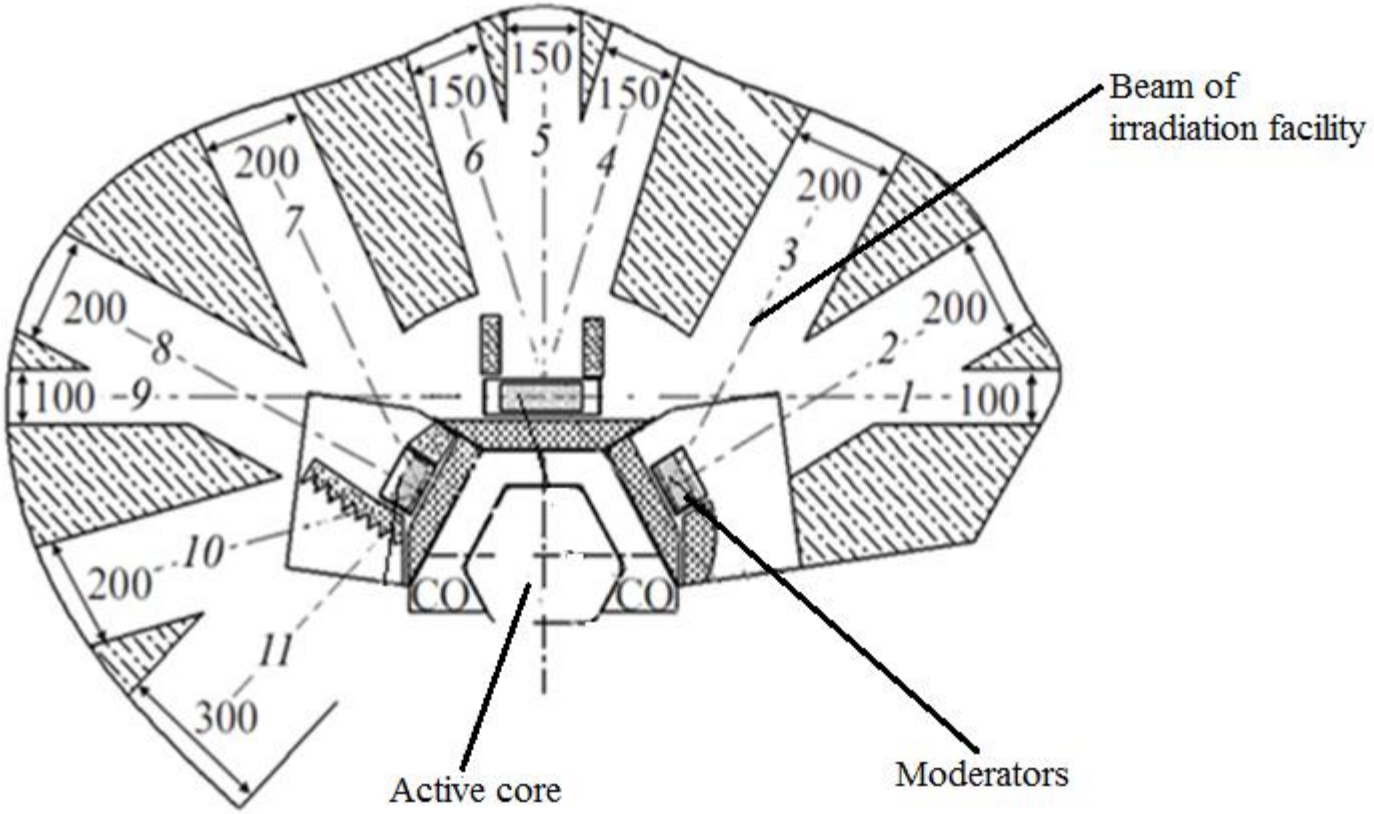
[14]**IAEA, Vienna, Austria**

[15]**Institute of archaeology,** Russian Academy of Sciences, Moscow, Russia

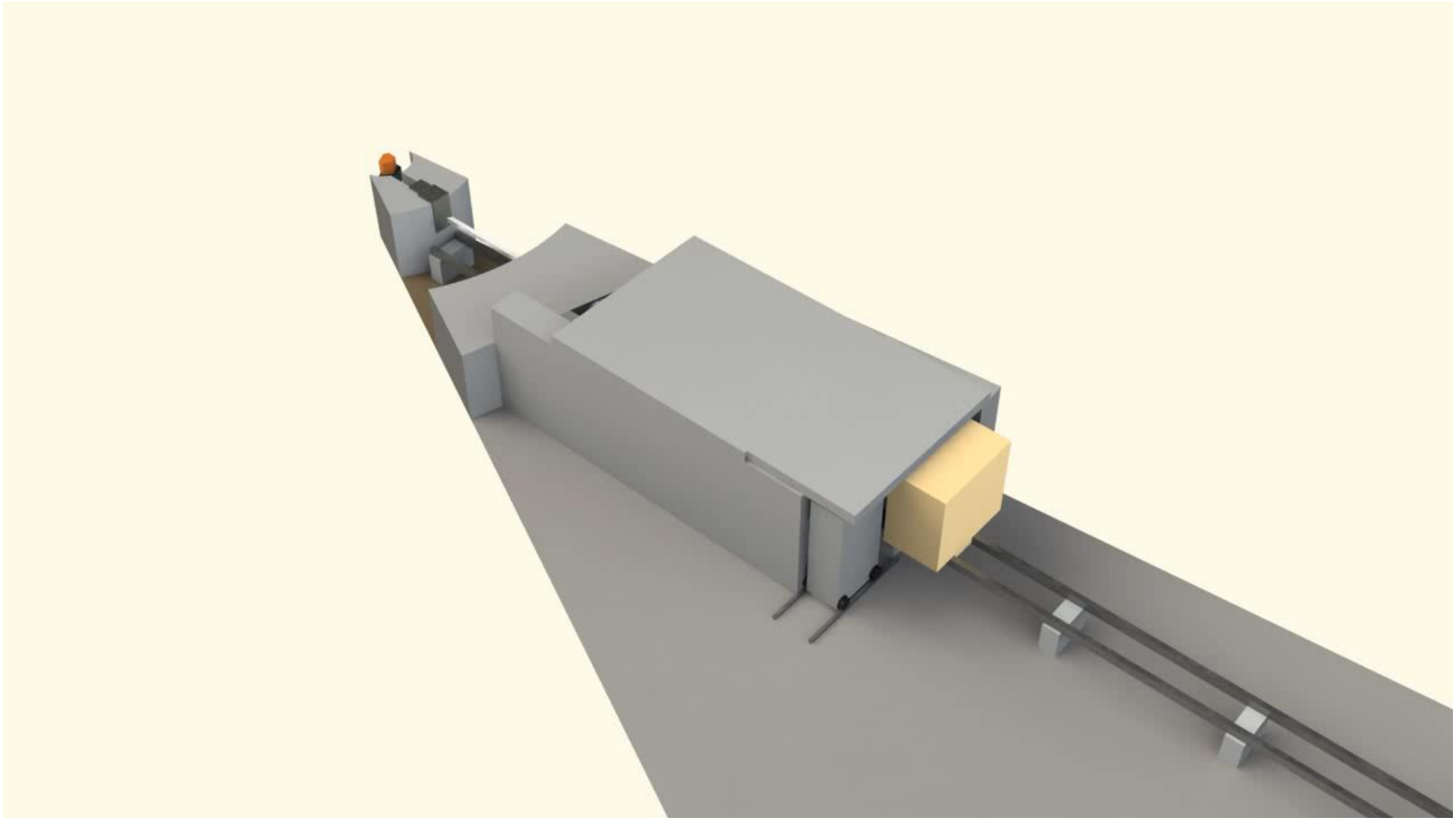
What are the fields and materials of research?

- Fusion reactors – ITER, DEMO – magnetic field sensors, uranium fission ionization detectors
- Coliders – LHC, NICA – research of diamond detectors, electronic boards, scintillators, graphene-based sensors, high-temperature super conductors' magnets
- Neutron scattering sample environment: IBR-2, ESS - choppers, neutron guides etc.
- Cold neutron moderators – radiation resistance of mesitylene, TPM
- Nuclear medicine – IBR-2 – first experiments of producing medical isotopes of ^{99m}Tc, ^{99}Mo, ^{131}I,^{193}Ir
- Mineralogy: radiation coloring of topazes
- Archeology and Biology: research of remains of king family from Moscow Kremlin, ancient pottery of Volga Bolgar, research of a *D. melanogaster* in radiobiology

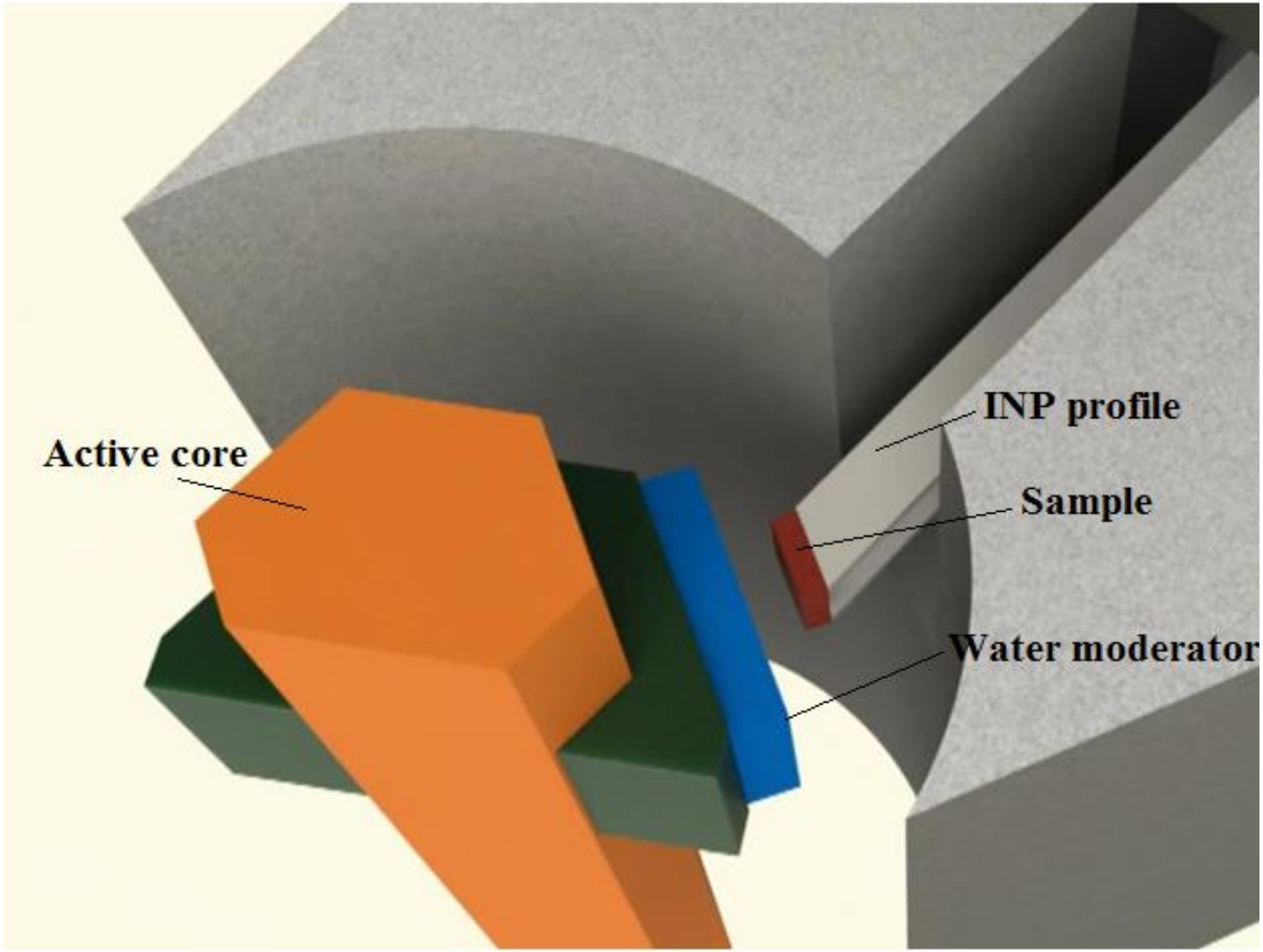
Experimental beamline of the irradiation facility



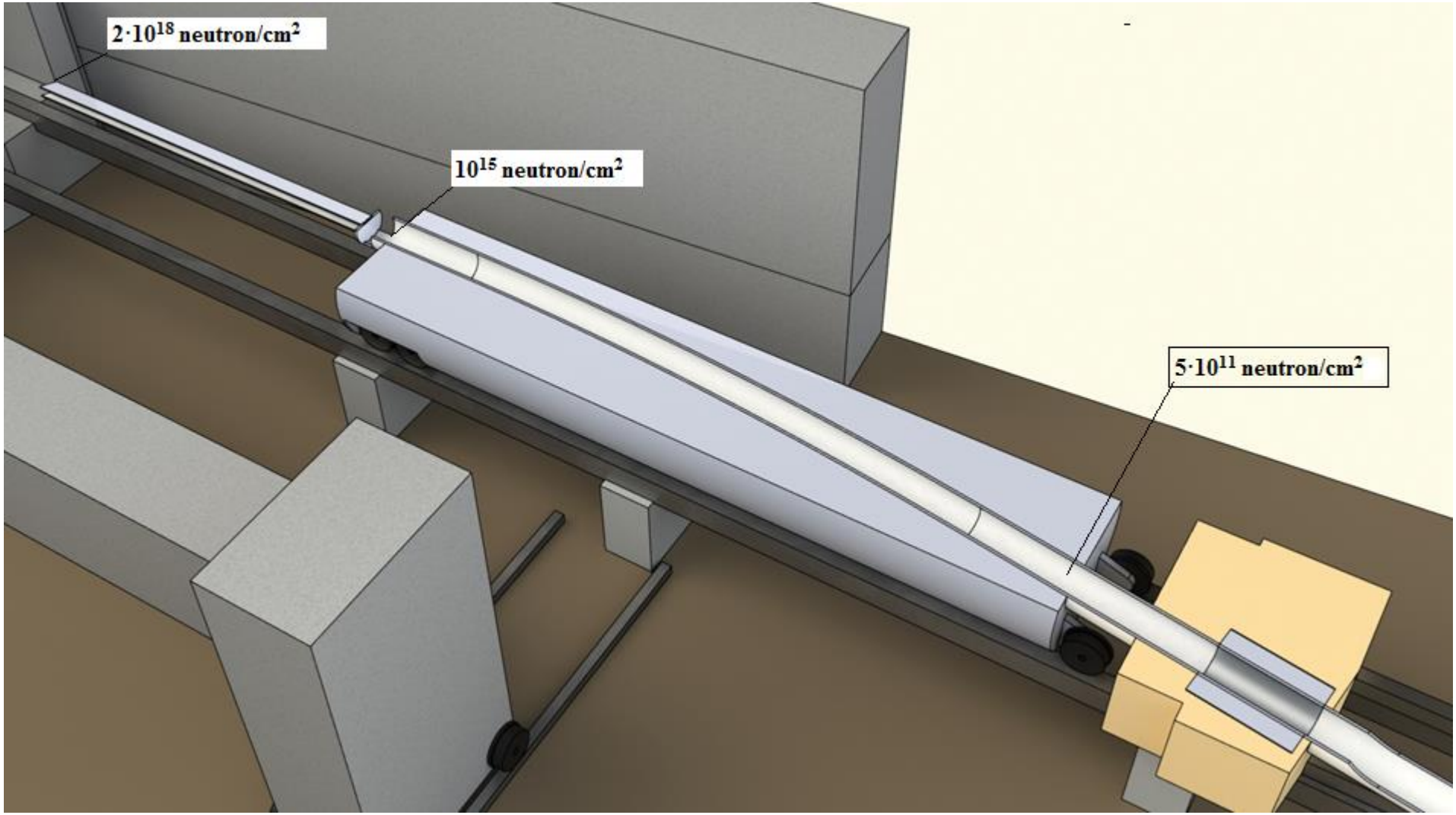
Irradiation facility



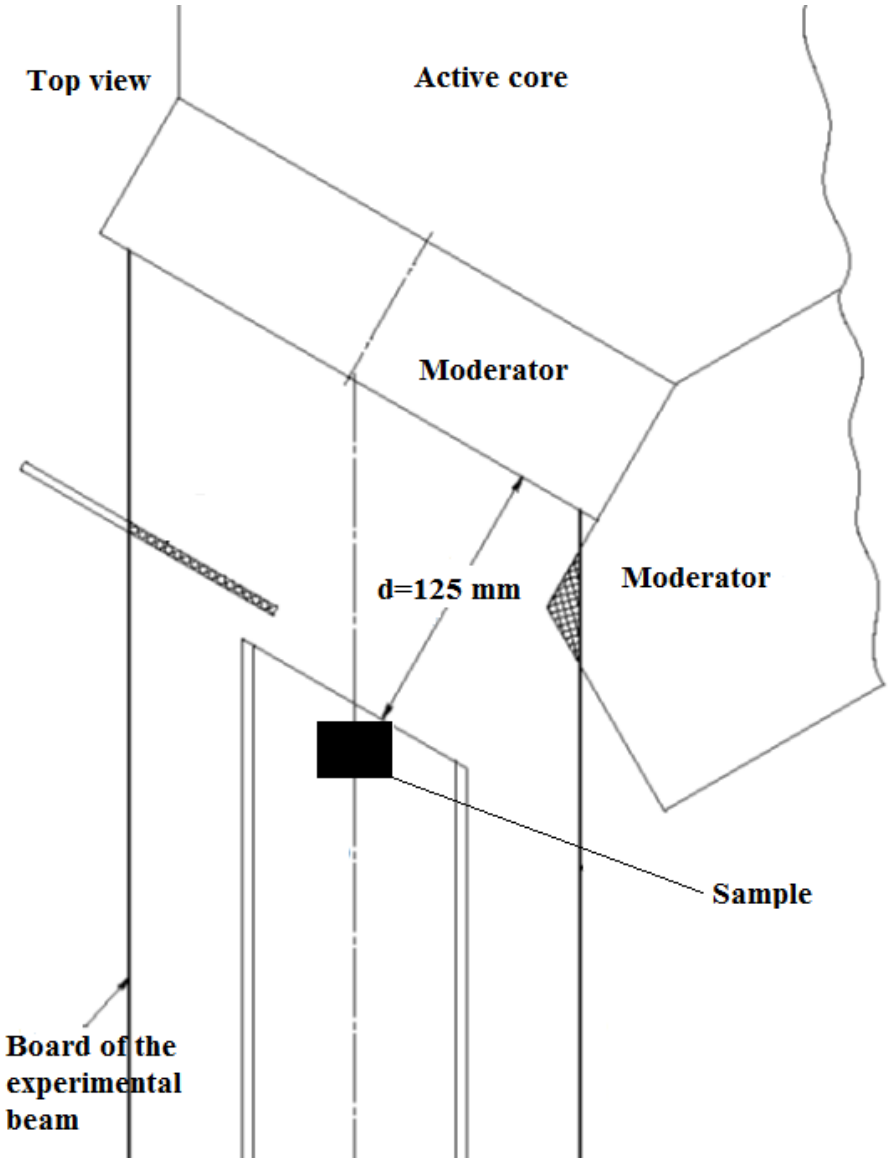
Irradiation facility

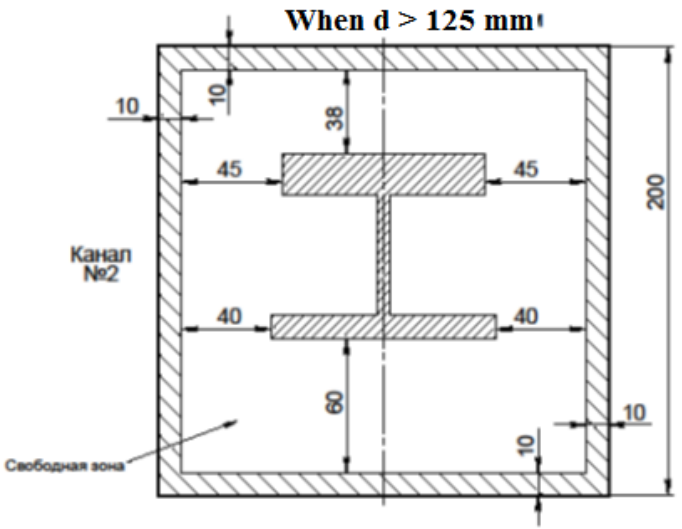


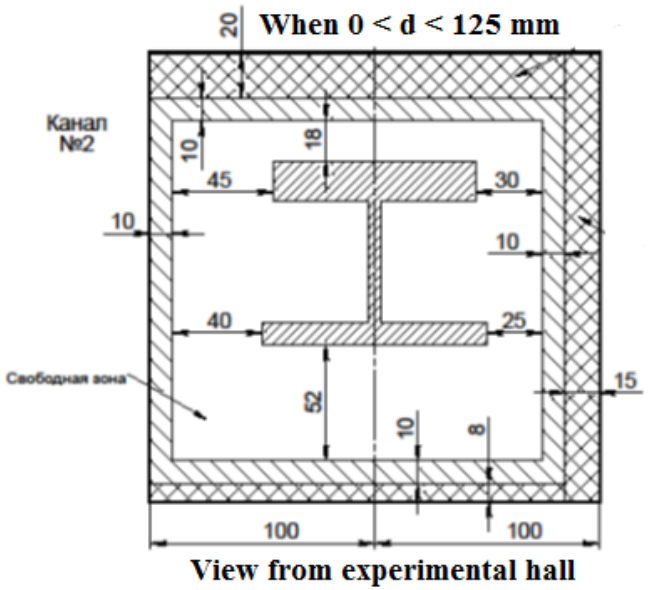
What neutron fluences do we have?



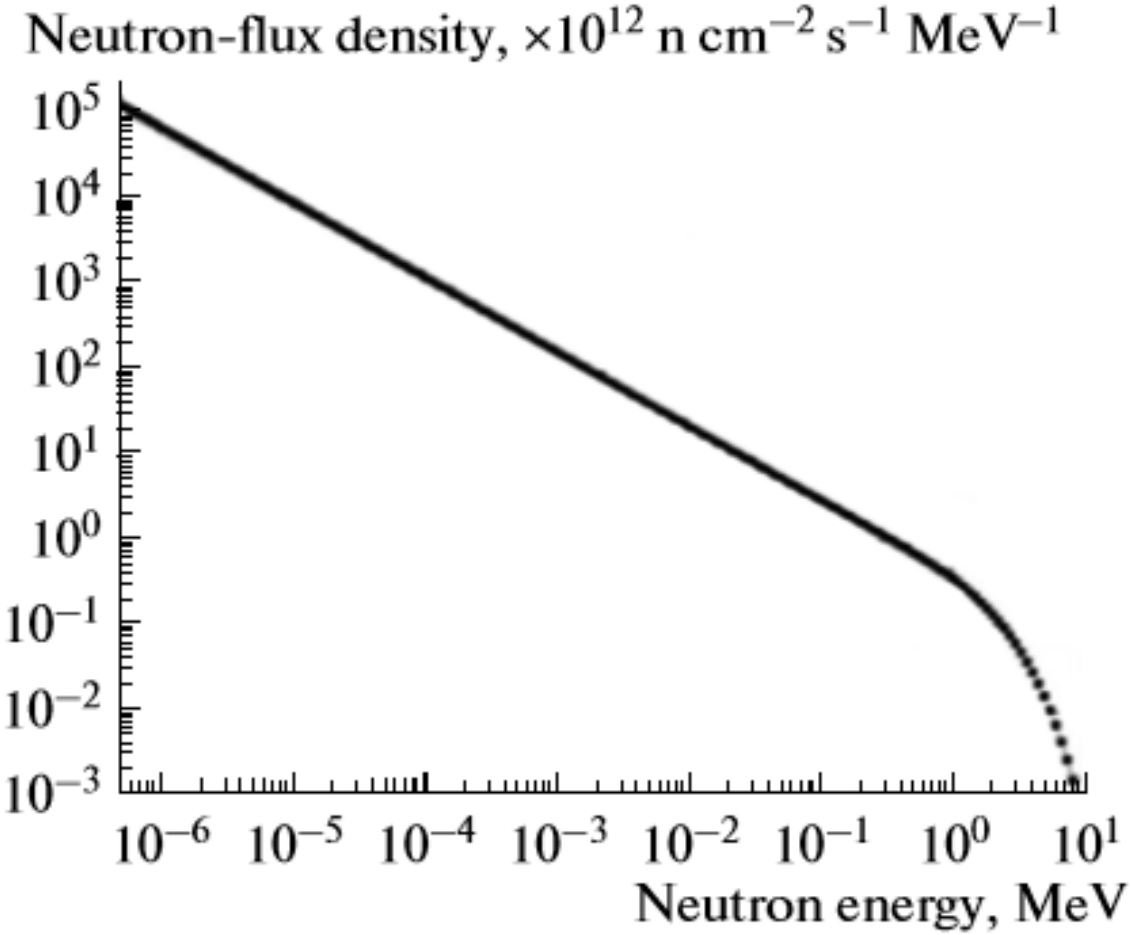
What size of samples we can irradiate?





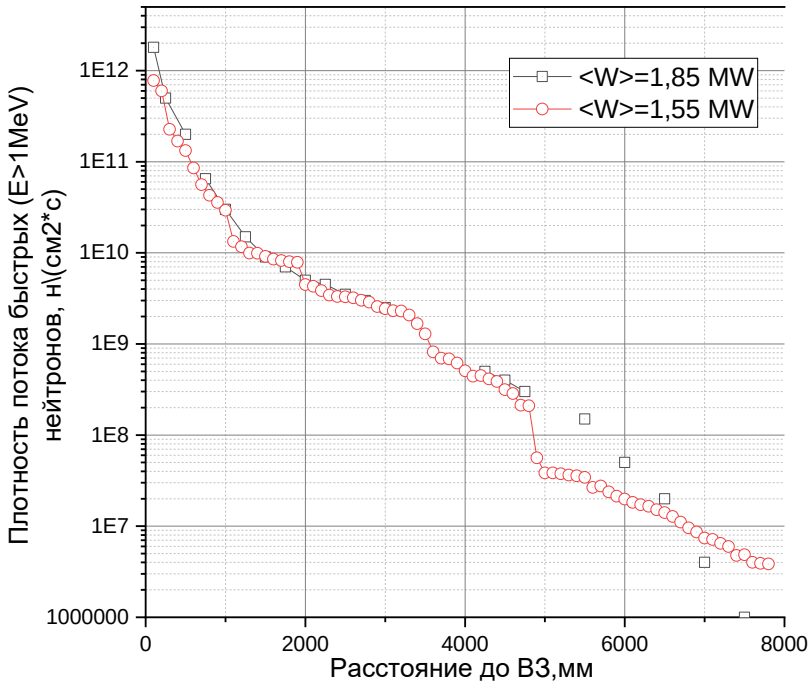


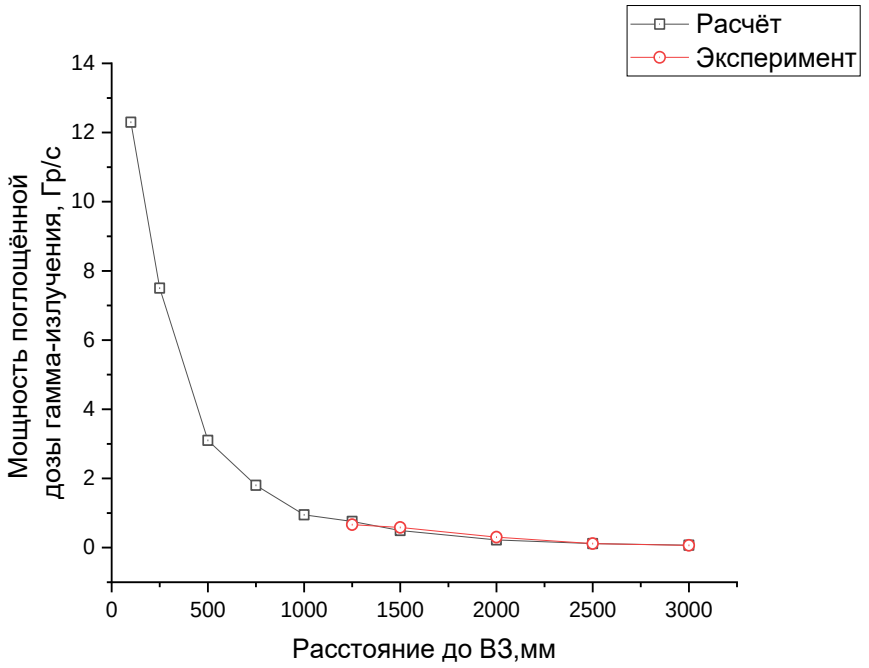
Neutron spectrum of the reactor



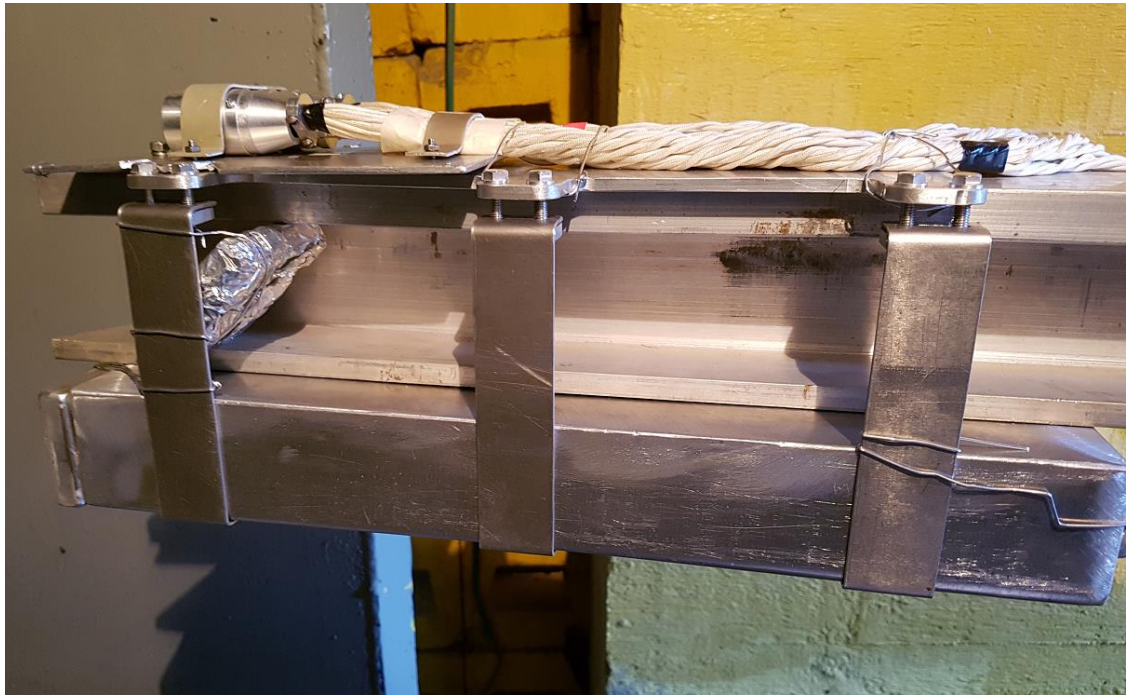
Irradiation facility at the IBR-2 reactor for investigating material radiation hardness / A. Cheplakov, M. Bulavin et al //Nuclear Instruments and Methods in Physics Research Section B Beam Interactions with Materials and Atoms 12(2), November 2014

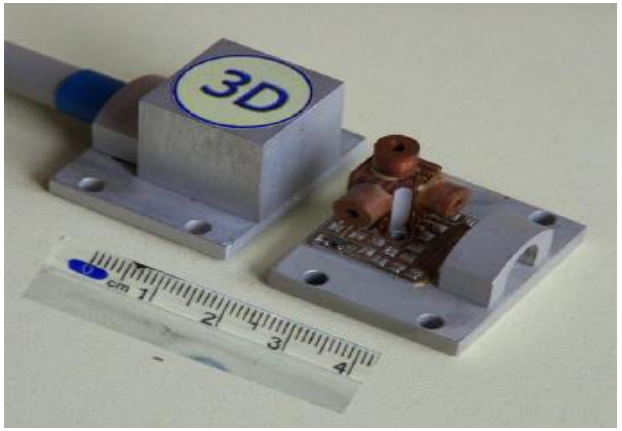
Dependence of neutron density flux from distance from moderator: fast neutrons





Irradiation of heads with metal Hall sensors samples for ITER and DEMO tokamaks projects and NICA





Now we get a fluence near 10^{20} n/cm^2 and metal sensors feel themselves very well

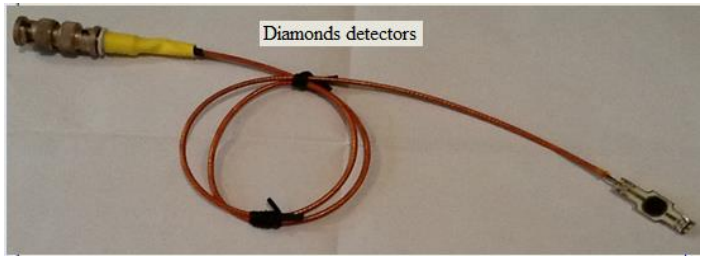
REFERENCES

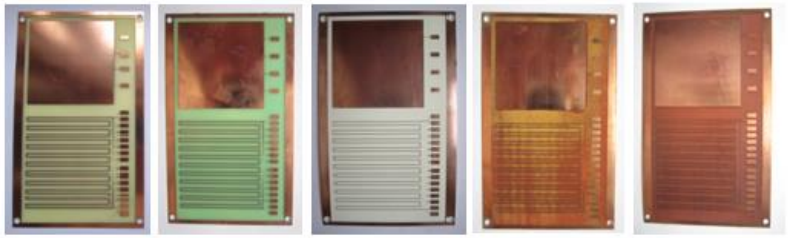
1. **Experimental evaluation of stable long term operation of semiconductor magnetic sensors at ITER relevant environment / I. Bolshakova [et al.] // Nuclear Fusion. – 2015. – Vol. 55. – №8. – P. 083006-083016**
2. **Metal Hall Sensors for the new generation fusion reactors of DEMO scale / I. Bolshakova et al // Nuclear fusion 57(11), June 2017**
3. **Graphene and prospects of radiation-hard Hall sensors / I.A. Bolshakova et al. // 2017 IEEE 7th International Conference on Nanomaterials: Applications & Properties (NAP – 2017). –Zatoka, Ukraine, 2017 – 03CBN15-3 – p. 1-4**
4. **Metal Nanofilms for Magnetic Field Sensors / A. Vasiliev et al. // 2017 IEEE 7th International Conference on Nanomaterials: Applications & Properties (NAP – 2017). – Zatoka, Ukraine, 2017 – 04NESP18-1 – p. 1-4**

Experiments

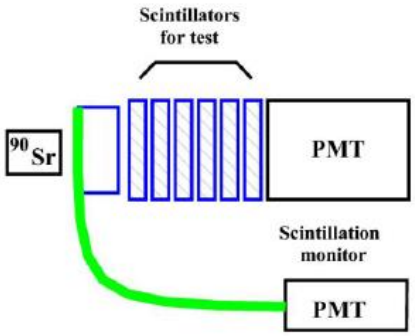
With LHC, CERN

mini Fcal, Detector Atlas, LHC



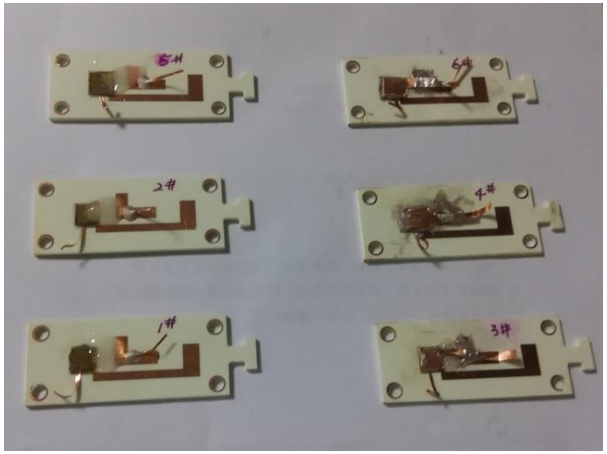


Electronic boards G10, FR4, Rogers, Arlon и полиимида.

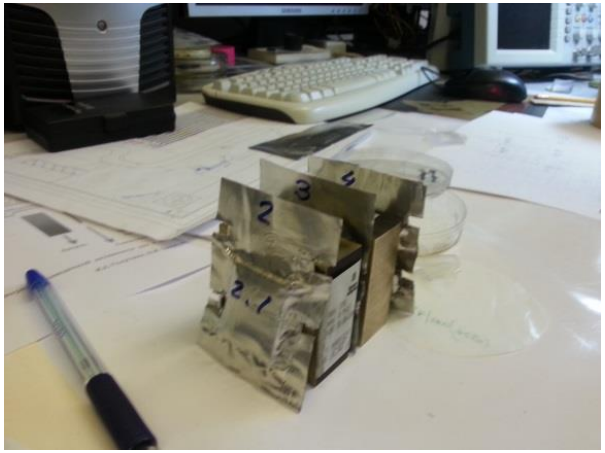


plastic SCSN-81 scintillator
CMS Hadron Calorimeter

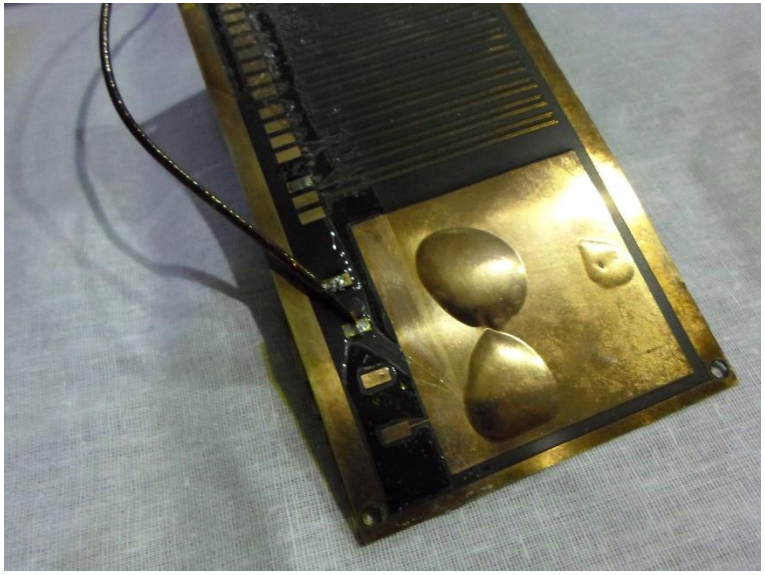
DD modules

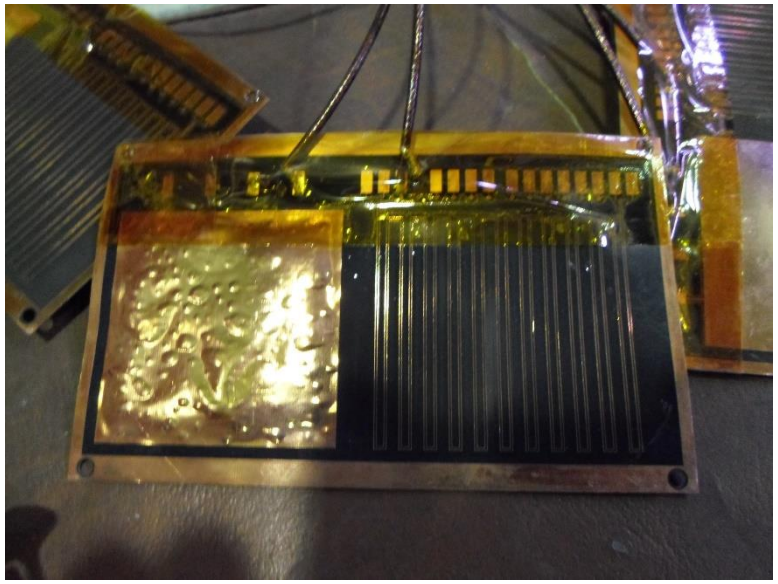


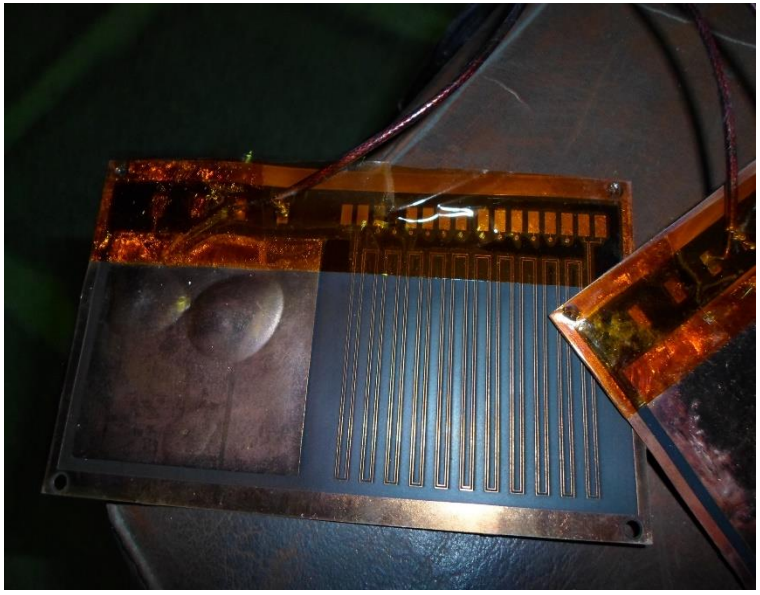
Scintillators, LHC

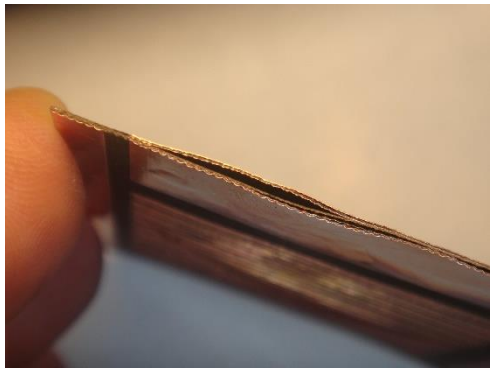


Electronic boards for ATLAS, CERN







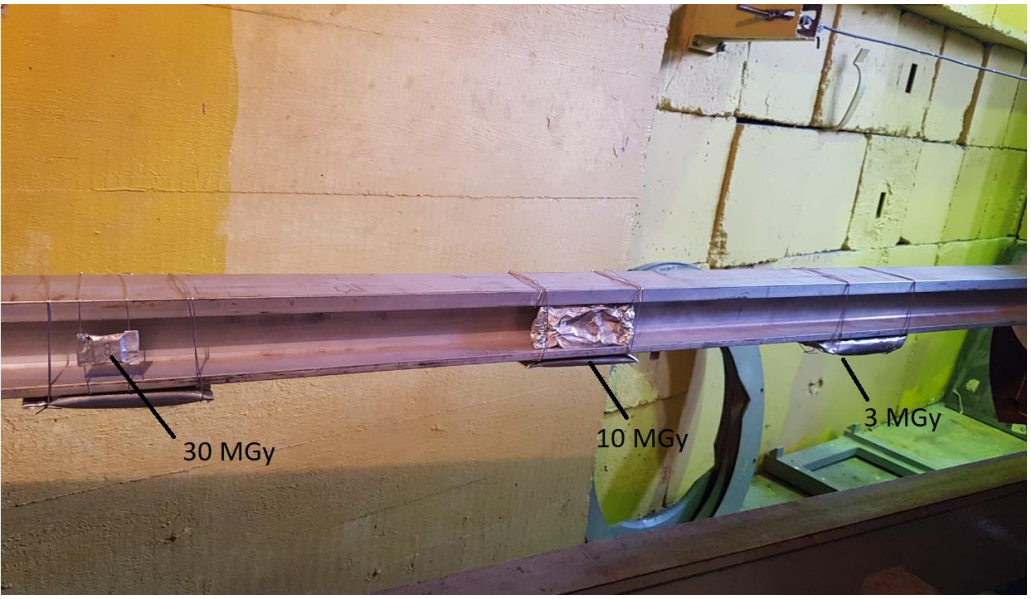


Electronic boards: G10, FR4, Arlon 85N, poliamid (copton), Rogers 4450B. Fast neutron fluence (E_n>0.4 MeV) ~ $4 \cdot 10^{17}$ n/cm^2.

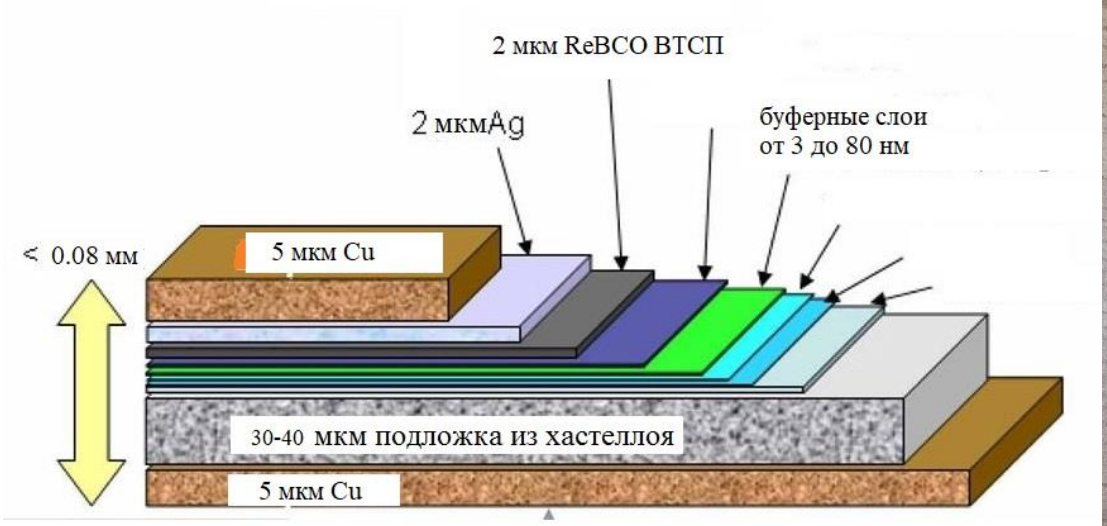
Most interesting detectors' materials irradiation publications

- Investigation of SCSN-81 scintillator irradiated by neutrons / S. Afanasiev [et al.] // CMS Internal Note. – 2013. – v. 2. – P. 1-4
- Radiation Hardness Investigation of PECVD Silicon Carbide Layers for PV Applications / J. Huran et al. // 40th Photovoltaic Specialists Conference (PVSC). – Denver, USA, 2014 – pp. 1815-1820
- Light yield and radiation hardness studies of scintillator strips with a filler / D. Chokheli et al // **Nuclear Instr. And Methods in Physics Res. A**, https://doi.org/10.1016/j.nima.2019.03.087, Vol. 930, pp 87-94
- Investigation of the radiation hardness of GaAs:Cr semiconductor detectors irradiated with fast neutrons at the reactor IBR-2 / U. Kruchonak et al // **Journal of Physics Conference Series**, ICPPA 2020, 1690 (2020) 012042, DOI: 10.1088/1742-6596/1690/1/012042
- Effects of high-energetic 3He+ ion irradiation on tungsten-based composites / E.P. Popov et al // **Vacuum**, Vol. 184, February 2021, 109934
- Investigation of the formation of defects under fast neutrons and gamma irradiation in 3C-SiC nano powder / Mirzayev M. N., Abdurakhimov B. A., Demir E., Donkov A. A., Popov E., Genov I.G., Thabethe T.T., Siemek K., Krezhov K., Mamedov F., Mirzayeva D.M., Bulavin, M.V., Turchenko V.A., Thang T.X., Abdurakhmonov T.Z., Horodek P. // **Physica B – Condensed Matter**, Vol. 611, № 412842

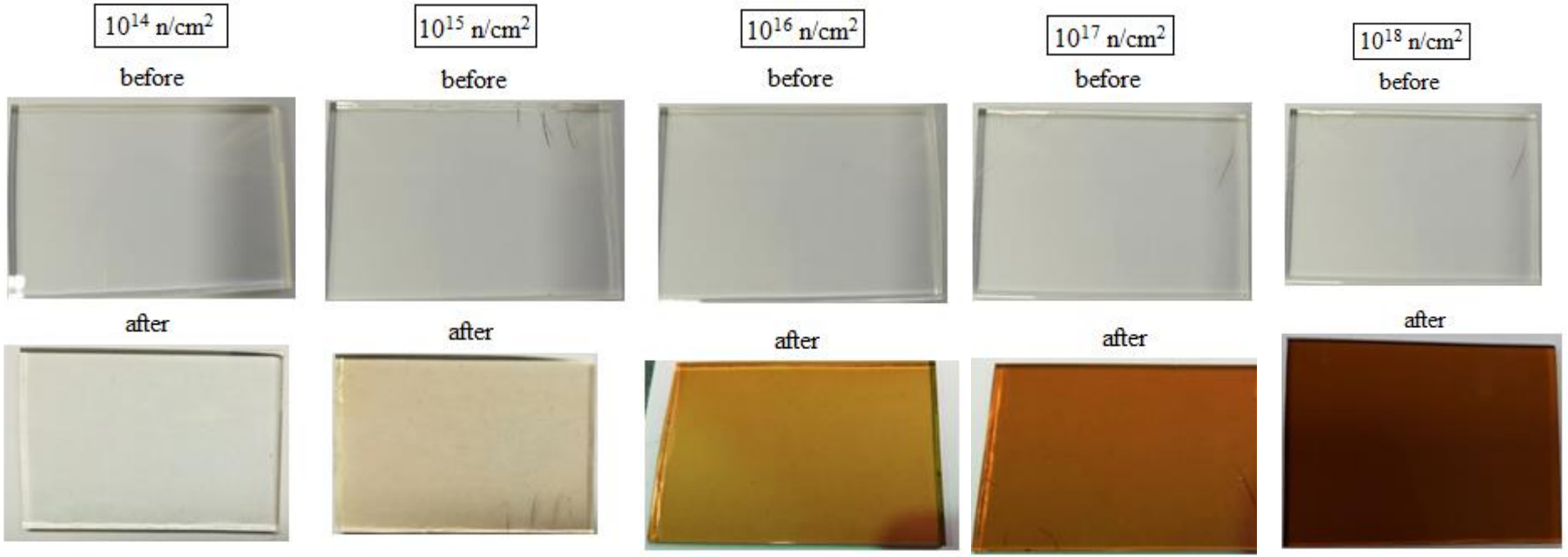
ESS Beam Choppers' materials



High-temperature super conductors' magnets

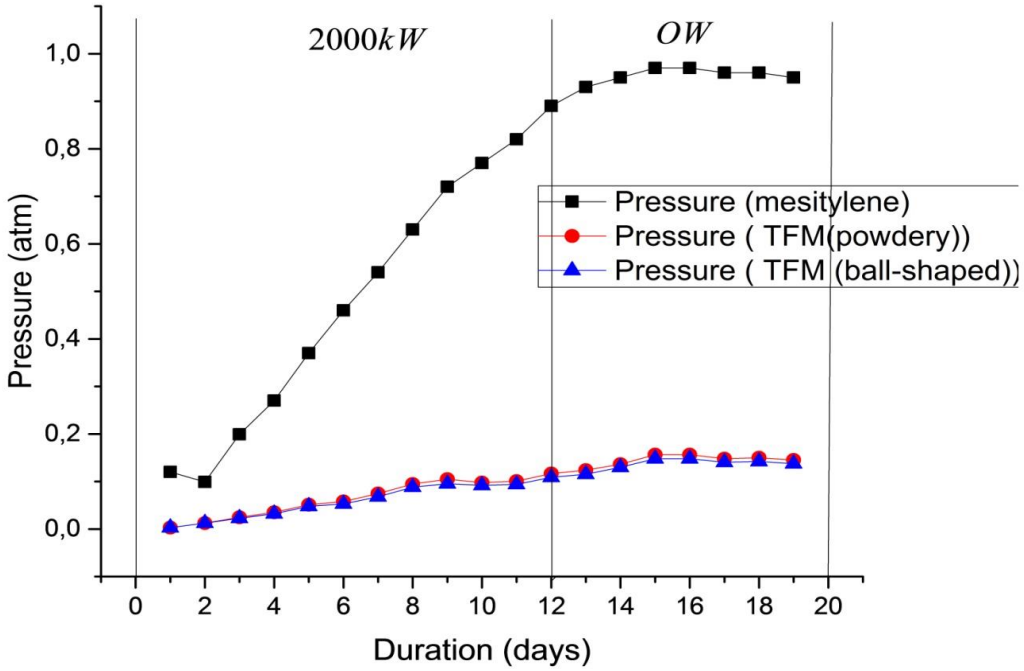


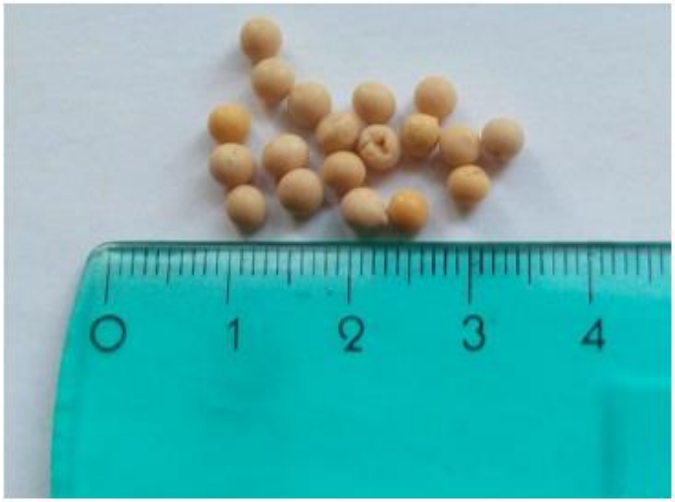
First results of neutron guide glasses irradiation



Glass						
K208	SiO_2	B_2O_3	K_2O	NaCl	Al_2O_3	CeO_2
%	76,92	10,56	9,59	0,97	1,38	0,58

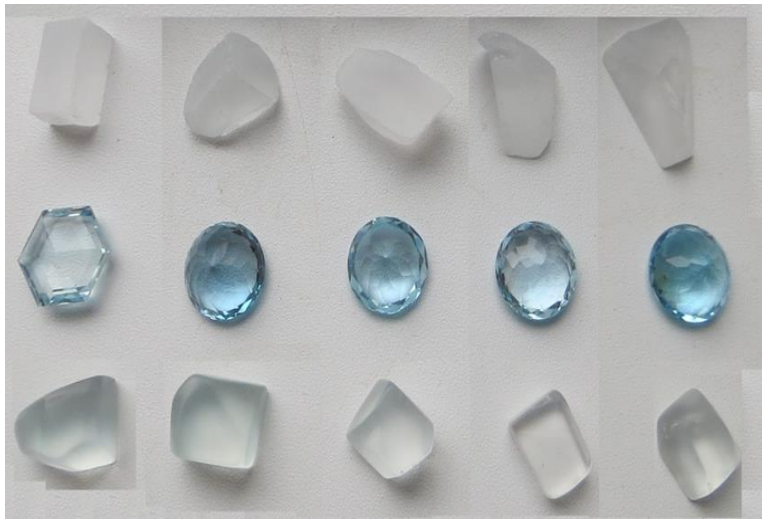
Radiation resistance of materials of cold moderators (at room temperature)

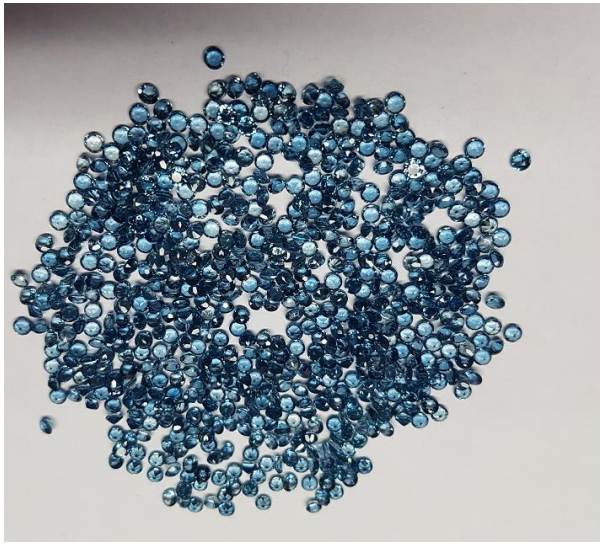




Radiation coloring of Topaz

Blue topaz is very popular in the gold work as jewelry. Yet, naturally occurring blue topaz is quite rare. For that reason, on the facility for the radiation research colorless topazes are irradiated up to fast neutron fluence of 10^{18} n/cm^2 to produce a more desired darker blue. The photo of topaz after the irradiation is shown in figure





Radiation coloring of Topaz

Study of Neutron Irradiation-Induced Color in Topaz at the Pulsed Reactor IBR-2 / Yu. Khatchenko et al // XXV International Seminar on Interaction of Neutrons with Nuclei (Neutron Spectroscopy, Nuclear Structure, Related Topics), Dubna, May 22-26, 2017

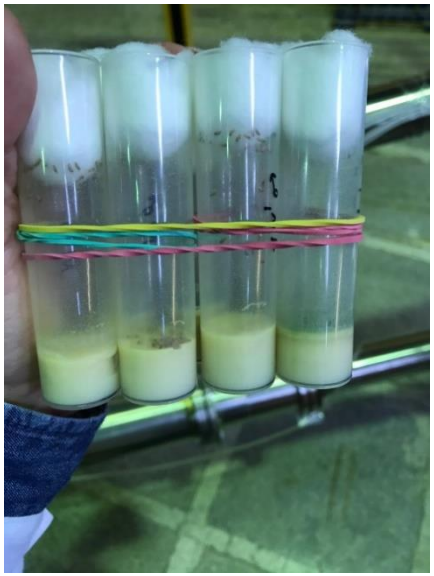
Archeology

Remains of the Ivan IV «The Terrible» king's family

bone

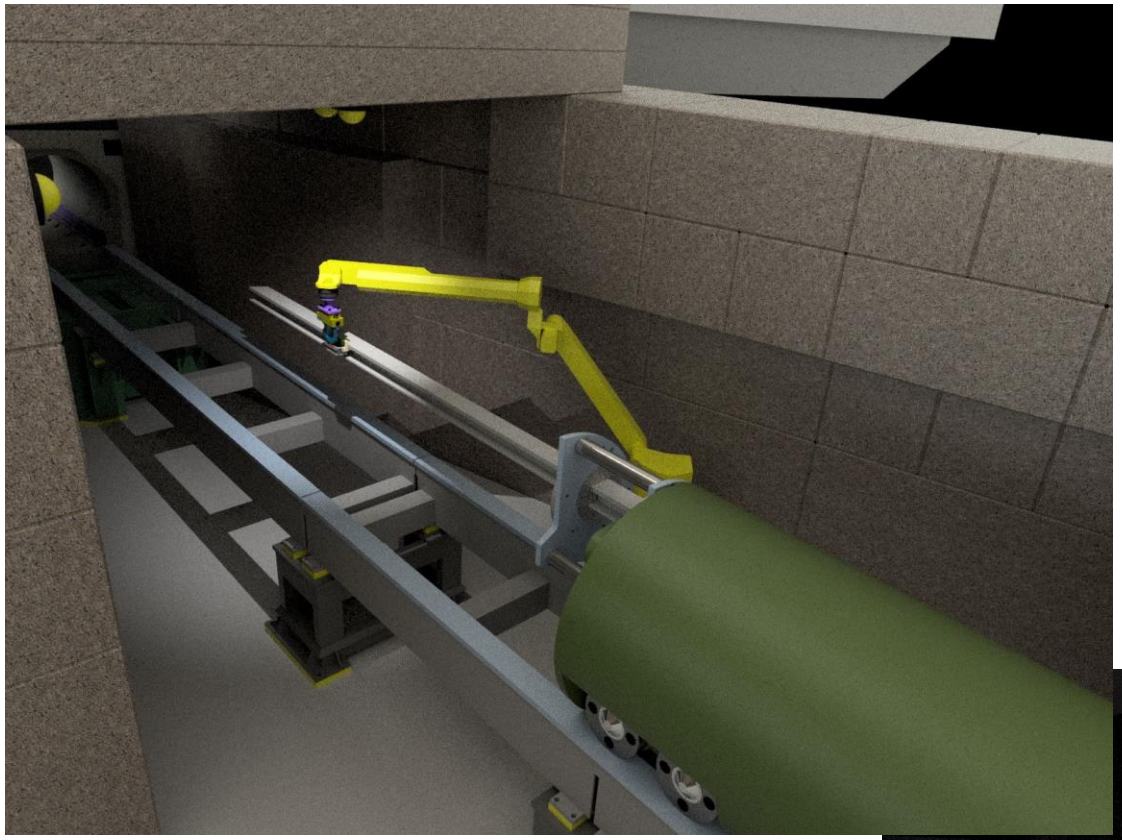
hair

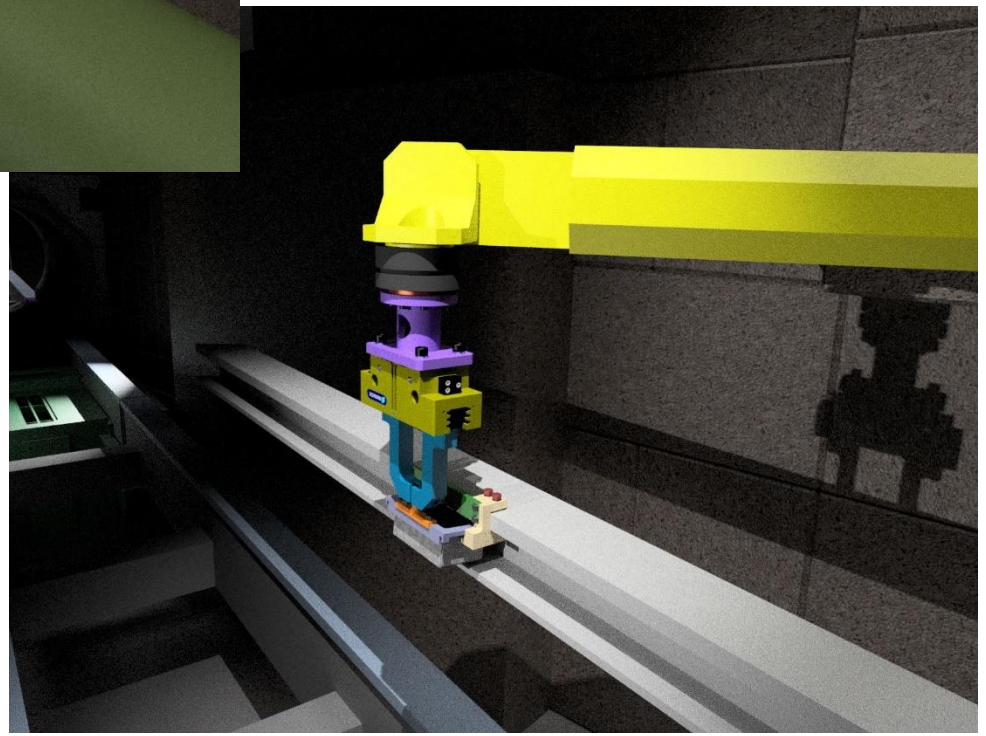
Radiobiology



D. melanogaster

Robotic arm for replacement the samples





Summary

1. Irradiation facility is a very important instrument for research of a radiation hardness with neutrons and gamma ray. It should be used together with another irradiation facility (based on accelerators) and complete to each other in International Innovation Centre of JINR
2. Irradiation facility is a really good instrument for prognoses of the radiation hardness of the different materials of MPD and SPD detectors of NICA during its operation (upgrade phases)
3. Irradiation facility allows to do an applied experiments of a radiation hardness of a different materials

Thank you for your attention!
Welcome to Dubna!