Condensed Matter Physics, Radiation and Radiobiological Research

Dzhelepov Laboratory of Nuclear Problems

Status and prospects of the DLNP scientific programme for 2024 - 2030

Development of Scientific DLNP Infrastructure for Research Using Semiconductor Detectors, Laser Metrology, Electrons, Positrons and Cryogenic Technology 04-2-1126-2015/2023

Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation 04-2-1132-2017/2023

Dzhelepov Laboratory of Nuclear Problems

Development of Scientific DLNP Infrastructure for Research Using Semiconductor Detectors, Laser Metrology, Electrons, Positrons and Cryogenic Technology 04-2-1126-2015/2023

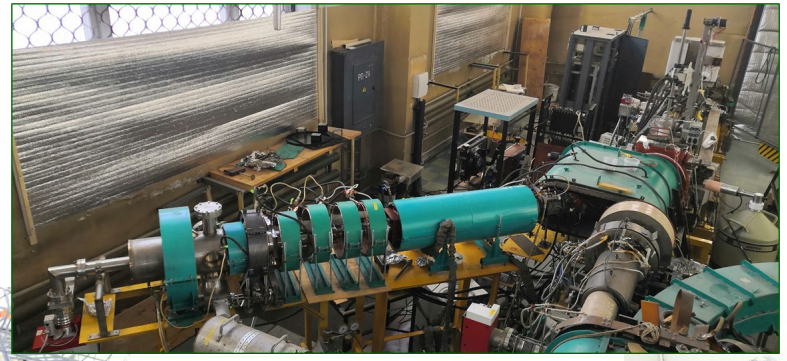
Construction of the setup for measurements with electron testbeams in DLNP (LINAC-200)

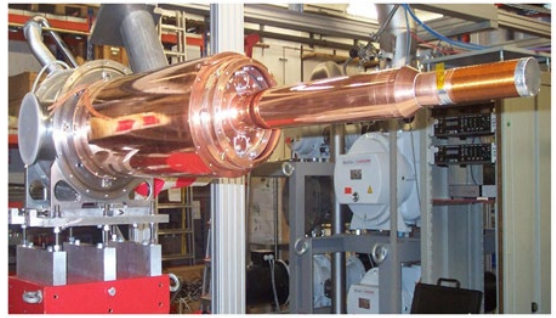
Project “Presicion laser metrology for accelerators and detector complexes”

Project "Development of experimental techniques and applied research with slow monochromatic positron beams (PAS)"

Project "Novel semiconductor detectors for fundamental and applied research"

“GDH & SPASCHARM” Project



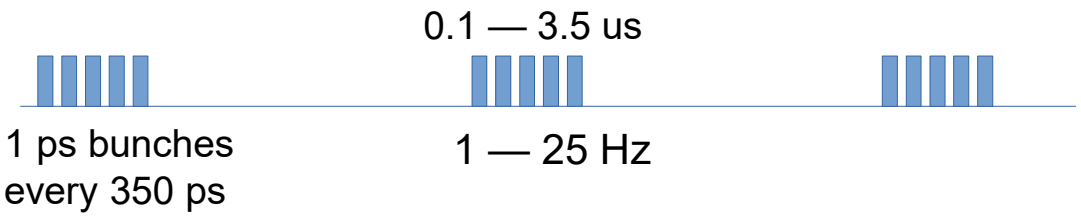


Construction of the setup for measurements with electron testbeams in DLNP (LINAC-200)

Linear electron accelerator LINAC200 - a new research facility of DLNP JINR

The machine

- Based on refurbished 800 MeV MEA (NIKHEF)
- LINAC200 = Injector, buncher and 4 (of 12) accelerating stations
- Two beam lines are available
  - 20 MeV (after the 1st station)
  - 20 – 200 MeV (after the 4th station).



- The beam energy spread is about 1%
- The beam current in a pulse can be set in the range from practically zero values (single electrons in a bunch) to 80 mA (up to 10^{14} e^- / s)
- The maximum average current is 2.5 μA.

Timeline

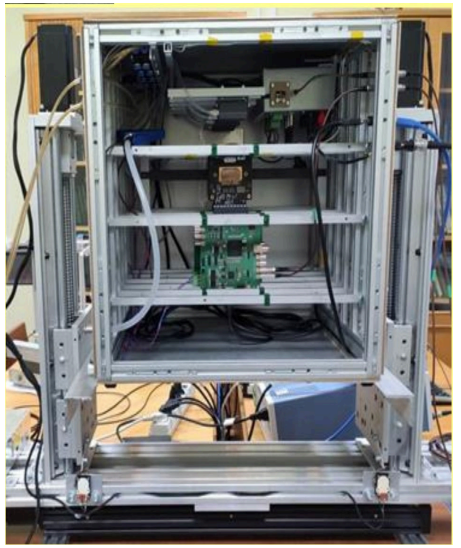
- Renovation of Bldg. 118 is complete
- LINAC200 commissioning is under way and expected to be completed by summer 2023
- The machine will continuously operate in 2024 - 2030
- Three projects are in preparation:

  - Testzone for detector R&D and applied studies
  - Controllable generation of EM radiation by relativistic electrons using functional materials
  - Electron radiography

Test zone for detector R&D and applied studies

Goal: to construct an open access user facility for particle detector R&D and applied studies, including material science, radiobiology etc.

- Beam characterization
- Photon and neutron beam generation
- Precise dosimetry
- Infrastructure & Equipment



Setup for Alpide testing at Linac-200

Controllable generation of EM radiation by relativistic electrons using functional materials

Goal: study of the basics of electromagnetic interactions and new applications of controllable generation of electromagnetic radiation by relativistic electrons using functional materials

- Study of relaxation of EM response of materials based on topological insulators and Dirac semimetals with super-high electron mobility excited by bunched electron beam
- Explore the possibility of control of phonon response of metamaterials excited by bunched electron beams
- Investigation of polarization radiation generation by electron beam on surface structures with high local electron density
- Generation of intense ultra-monochromatic THz and sub-THz radiation. Construction of the THz radiation source for radiobiological research
- Application to the accelerator diagnostics R&D

FLAP Collaboration

ОИЯИ

НИУ БелГУ BELGOROD STATE UNIVERSITY (BSU)

TOMSK POLYTECHNIC UNIVERSITY

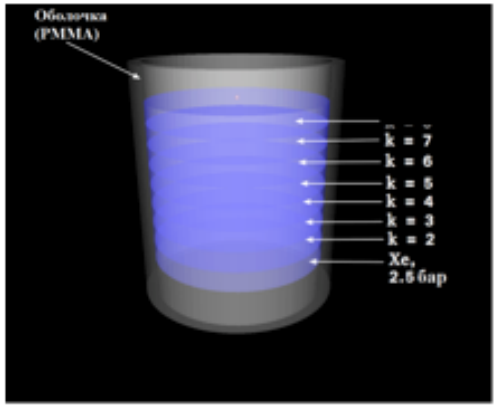
Universidad Andrés Bello

KEK High Energy Accelerator Research Organization

РФЯЦ ВНИИЭФ

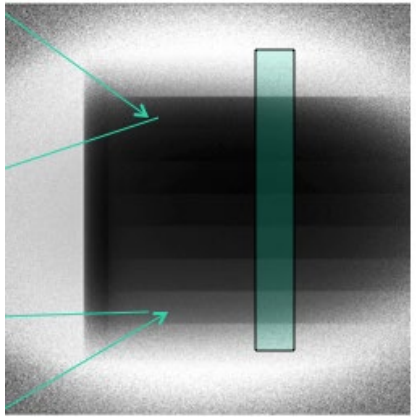
POLYTECH Peter the Great St.Petersburg Polytechnic University

Electron radiography



Goal: Implementation of electron radiography technique, construction of the electron microscope with an energy of 200 MeV to measure the density distribution in dynamic and static objects with a linear density of up to 10 g/cm2.

- Two radiography setups
  - Fast processes, FOV 20 mm and resolution 100 um
  - Static objects, FOV 10 mm and resolution 10 um
- Development of reconstruction methods and software
- Study of dynamic processes in porous materials and non-ideal plasma of shock-compressed inert gases
- Development of new structural materials
- Flaw detection research.



National Research Center
"Kurchatov Institute"

Institute for Problems of Chemical Physics RAS

Education & training

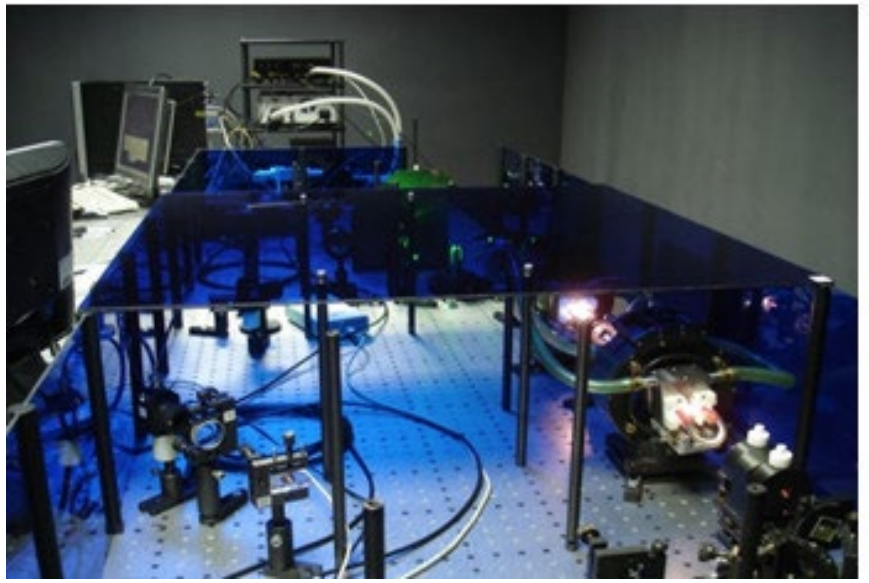
LINAC200 is an excellent place to train young scientists and engineers:

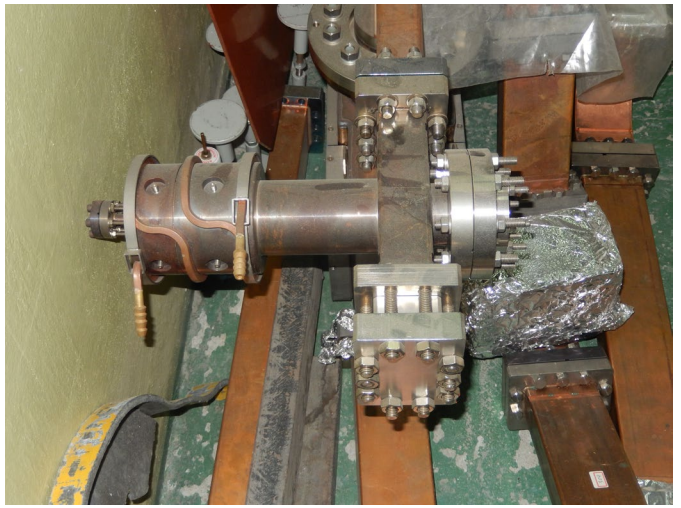
- Accelerator physics and technology
- Particle detector characterization
- Toy experiments (e.g. measurement of nuclear form factors and GDR)
- Radiation material science, generation and registration of synchrotron and THz radiation, etc

Work together with the University Center

Accelerator R&D and upgrade plan

- Design and construction of the photoinjector
  - Possible replacement of the electron gun
  - R&D on generation of twisted electrons (together with ITMO)
- Preparation of LINAC200 upgrade up to 800 MeV
  - Refurbishing old MEA parts
  - Upgrade of control and vacuum system





Thanks for participating in the commissioning LINAC200 RUN

TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
«National Research Tomsk Polytechnic University» (TPU)
30, Lenin ave., Tomsk, 634050, Russia
Tel. +7-3822-606333, +7-3822-701779,
Fax +7-3822-606444, e-mail: tpu@tpu.ru, tpu.ru
OKPO (National Classification of Enterprises and Organizations): 02069303,
Company Number: 027000890168,
VAT/KPP (Code of Reason for Registration)
7018007264/701701001, BIC 016902004

Министерство науки и высшего образования Российской Федерации
федеральное государственное автономное образовательное
учреждение высшего образования
«Национальный исследовательский
Томский политехнический университет» (ТПУ)
Ленина, пр., д. 30, г. Томск, 634050, Россия
тел.:+7-3822-606333, +7-3822-701779,
факс +7-3822-606444, e-mail: tpu@tpu.ru, tpu.ru
ОКПО 02069303, ОГРН 1027000890168,
ИНН/КПП 7018007264/701701001, БИК 016902004

08.11.2022 № 01/8309
на № _____ от _____

О проведении исследований

Директору Объединенного
института ядерных исследований
Академику
Трубникову Г.В.
141980 Московская обл., г. Дубна,
ул. Жолио-Кюри, д.6

Уважаемый Григорий Владимирович!

В период с 10 по 15 октября физики нашего университета провели тестовый сеанс по калибровке диагностической аппаратуры на пучке электронов ускорителя ЛИНАК 200 в рамках коллаборации FLAP (координатор – д.ф.-м.н. А.А. Балдин). От имени ТПУ выражаю признательность коллективу ускорителя ЛИНАК 200 (рук. – В.В. Кобец) за возможность выполнения калибровочных измерений при проведении пусконаладочных работ на ускорителе. Разрабатываемое диагностическое оборудование планируется использовать для мониторирования параметров выведенного пучка нуклотрона, а также пучков коллайдера NICA.

Надеюсь на успешное продолжение экспериментальных исследований и развитие сотрудничества с ОИЯИ, в том числе, при подготовке специалистов-физиков.

Ректор Д.А. Седнев

Сухих Л.Г.
+7 (3822) 70-17-77
Sukhikh@tpu.ru

МИНОБРНАУКИ РОССИИ
ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ АВТОНОМНОЕ
ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ОБРАЗОВАНИЯ
«БЕЛГОРОДСКИЙ ГОСУДАРСТВЕННЫЙ НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ» (НИУ «БелГУ»)

НИУ БелГУ
BELGOROD STATE UNIVERSITY (BSU)

Победы ул., д. 85, г. Белгород, 308015; e-mail: info@bsu.edu.ru,
тел.: (4722) 30-12-11, факс 30-10-12, Web: http://www.bsu.edu.ru
ОКПО 02079230, ОГРН 1023101664519, ИНН/КПП 3123035312/312301001

16.11.2022 № 0-2759
№ _____ от _____

Директору Объединенного
института ядерных исследований
Трубникову Г.В.

Глубокоуважаемый Григорий Владимирович!

НИУ БелГУ принял участие в пуско-наладочных работах с пучками ускоренных электронов линейного ускорителя LINAC-200 Объединенного института ядерных исследований.

Благодарим координатора коллаборации FLAP Антона Александровича Балдина и руководителя запуском ускорителя LINAC-200 Валерия Васильевича Кобеца за предоставленную уникальную возможность принять участие в работах по пусконаладочных работах.

НИУ «БелГУ» выражает заинтересованность в дальнейшем проведении совместных исследований в рамках деятельности научно-исследовательской коллаборации FLAP. В рамках коллаборации FLAP успешно проведены первые пробные измерения. Линейный ускоритель электронов LINAC-200 уникален по своим характеристикам. Тематика проводимых исследований является одним из приоритетных направлений развития нашего университета. Мы готовы осуществить интеллектуальный и материально-технический вклад в развитие данного направления экспериментальных исследований в виде разработки и создания научно-исследовательских станций для изучения механизмов формирования электромагнитного излучения пучками ускоренных электронов. Наша деятельность также нацелена на разработку и испытание новых неинвазивных методов мониторирования пучков, которые будут использоваться на ускорительном комплексе NICA.

Проректор по науке и инновациям Репников Н.И.

Кубанкин А.С.

РФЯЦ-ВНИИЭФ
РОСАТОМ

Федеральное государственное унитарное предприятие
РОССИЙСКИЙ ФЕДЕРАЛЬНЫЙ ЯДЕРНЫЙ ЦЕНТР
Всероссийский научно-исследовательскийинститут экспериментальной физики
(ФГУП «РФЯЦ–ВНИИЭФ»)

пр. Мира, д.37,
г. Саров, Нижегородская обл., 607188
Факс: 83130 29494 E-mail: staff@vniief.ru
Телетайп: 151535 «Мимоза»
ОКПО 07623615, ОГРН 1025202199791
ИНН 5254001230, КПП 525401001

27.10.2022 № 195-03/41923
На № _____ от _____

О перспективе совместных работ

Директору Международной
межправительственной организации
Объединенный институт ядерных
исследований, академику РАН
Трубникову Григорию Владимировичу

ул. Жолио-Кюри, 6
г. Дубна, Московская обл.,
141980

Уважаемый Григорий Владимирович!

Выражаем искреннюю благодарность дирекции и руководству ОИЯИ за оказанную поддержку первых (пробных) экспериментов с пучками ускорителя ЛИНАК-200 и за предоставленную возможность экспериментального тестирования методик нейтронных измерений в режиме пусконаладочных работ ускорителя.

Выполненные в 2022-м году измерения технических параметров нейтронного источника, получаемого при облучении разного типа конверторов электронным пучком ускорителя ЛИНАК-200 показали реальную перспективу разработки и создания калибровочного стенда для методик импульсных нейтронных измерений. Калибровка аппаратуры образцовым нейтронным излучением, которое можно получать с помощью ЛИНАК-200, востребована не только подразделениями ВНИИЭФ, но и другими организациями, в том числе, участниками коллаборации FLAP.

Отдельную благодарность хотелось бы выразить координатору работ А.А. Балдину и команде специалистов, обеспечивающих работу ускорителя во главе с В.В. Кобецем. Рассчитываем на дальнейшее плодотворное сотрудничество и достижение новых результатов мирового уровня.

И.о. директора ИФВ А.О. Бликов

Cost estimate (kUSD)

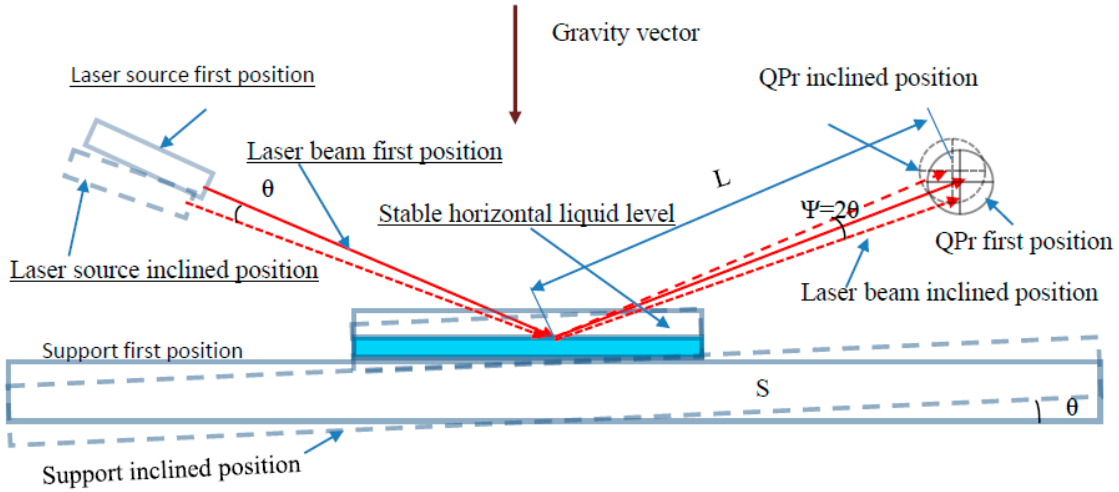
	2024	2025	2026	2027	2028	2029	2030	**Total**
LINAC200 maintenance & operation	100	100	100	100	100	100	100	**700**
Research projects	400	400	400	400	400	400	400	**2800**
Total	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**3500**

Dzhelepov Laboratory of Nuclear Problems

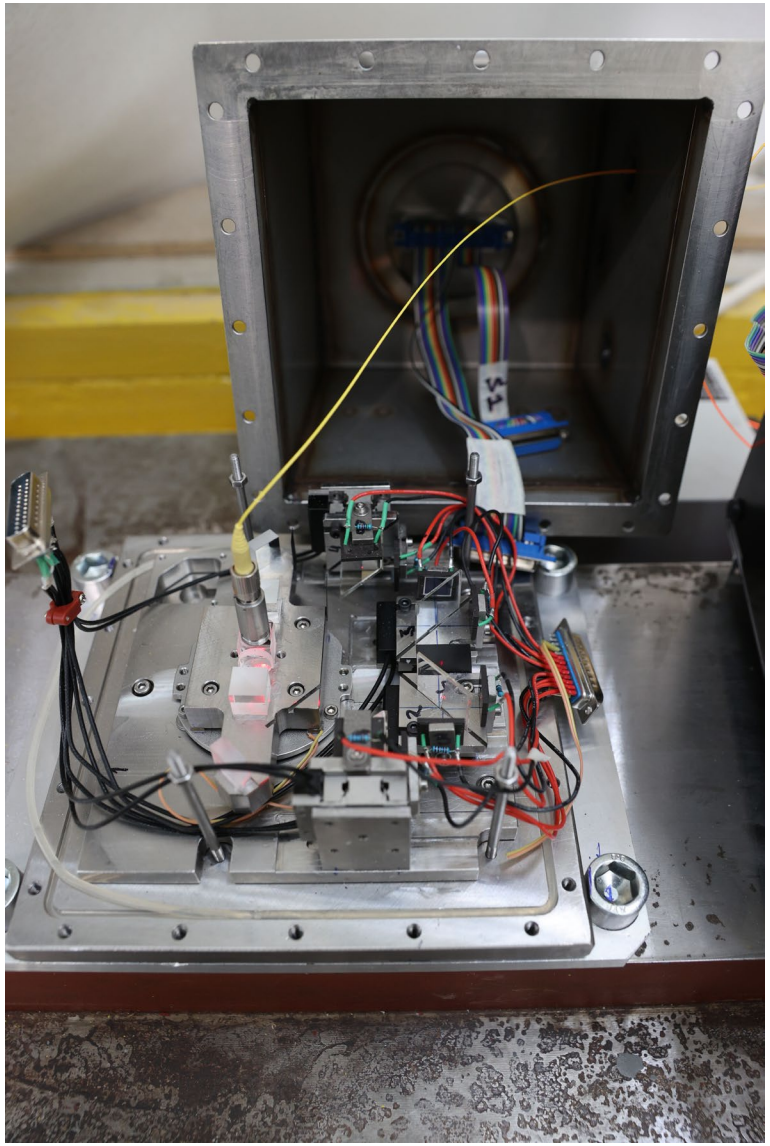
Project “Presicion laser metrology for accelerators and detector complexes”

M.V. Lyablin V.V. Glagolev

The Precision Laser Inclinometer (basic idea)



- The main idea is to use the effect of horizontality of surface of the liquid.
- Angular displacement of the laser beam reflected from the surface of the liquid is proportional to the inclination of the support with cuvette with liquid



Dzhelepov Laboratory of Nuclear Problems

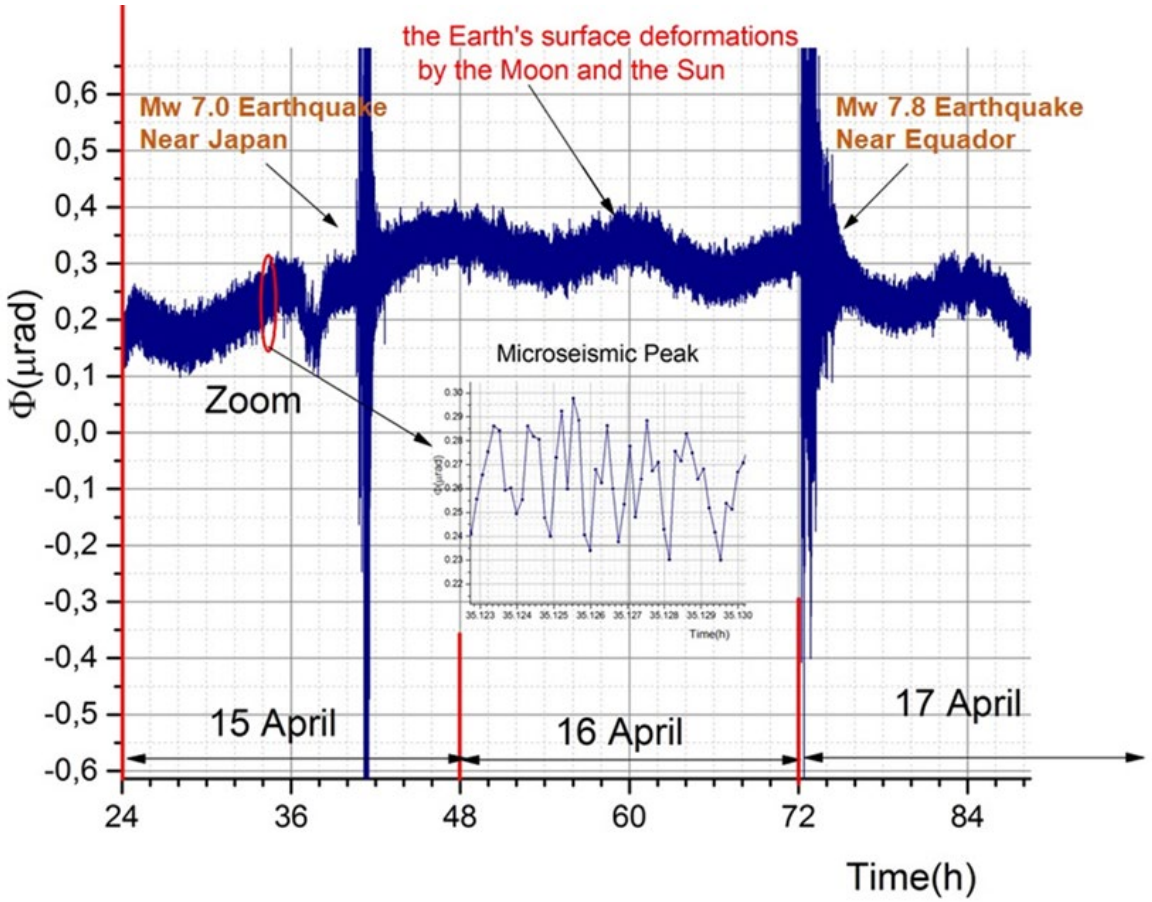
Project “Presicion laser metrology for accelerators and detector complexes”

DEVELOPMENT OF DLNP SCIENTISTS

Unique detector of angular oscillations of the Earth's surface in two orthogonal directions:

- frequency range - upper limit about **15 Hz**
- Sensitivity (laser reference beam stability) **10^{-9} rad**

The device detects the angular inclinations of the Earth's surface, excited by the Moon, the Sun, remote earthquakes, microseismic peaks and sources of industrial origin



Dzhelepov Laboratory of Nuclear Problems

Project “Presicion laser metrology for accelerators and detector complexes”

ПОЗДРАВЛЯЕМ!

Отдел лицензий и интеллектуальной собственности сообщает о получении патента ОИЯИ

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2747047

ЛАЗЕРНЫЙ ИНКЛИНОМЕТР

Патентообладатель: *Объединенный институт ядерных исследований (ОИЯИ) (RU)*

Авторы: *Будагов Юлиан Арамович (RU), Ляблин Михаил Васильевич (RU)*

Заявка № 2020127809
Приоритет изобретения 19 августа 2020 г.
Дата государственной регистрации в Государственном реестре изобретений Российской Федерации 23 апреля 2021 г.
Срок действия исключительного права на изобретение истекает 19 августа 2040 г.

Руководитель Федеральной службы по интеллектуальной собственности Г.П. Ивлиев

ОЛИС, пл.ЛЯП, корп.113, 1-й эт. к.101 - 1
e-mail: grlan@jinr.ru тел. 21-65862 21-62

РОССИЙСКАЯ ФЕДЕРАЦ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2740489

Лазерный инклинометр для длительной ре
угловых наклонов земной поверхнос

Патентообладатель: *Объединенный институт ядер исследований (ОИЯИ) (RU)*

Авторы: *Будагов Юлиан Арамович (RU), Ляблин Михаил Васильевич (RU)*

Заявка № 2020122047
Приоритет изобретения 29 июня 2020
Дата государственной регистрации в Государственном реестре изобретений Российской Федерации 14 января 202
Срок действия исключительного права на изобретение истекает 29 июня 2040

Руководитель Федеральной службы по интеллектуальной собственности Г.П. Ивлиев

ПОЗДРАВЛЯЕМ!

Отдел лицензий и интеллектуальной собственности сообщает о получении патента

РОССИЙСКАЯ ФЕДЕРАЦИЯ

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2734451

УСТРОЙСТВО ДЛЯ ИЗМЕРЕНИЯ УГЛОВ НАКЛОН
ПОВЕРХНОСТИ

Патентообладатель: *Объединенный институт ядерных исследований (ОИЯИ) (RU)*

Авторы: *Будагов Юлиан Арамович (RU), Ляблин Михаил Васильевич (RU)*

Заявка № 2020106355
Приоритет изобретения 11 февраля 2020 г.
Дата государственной регистрации в Государственном реестре изобретений Российской Федерации 16 октября 2020 г.
Срок действия исключительного права на изобретение истекает 11 февраля 2040 г.

Руководитель Федеральной службы по интеллектуальной собственности

ОЛИС, пл.ЛЯП, корп.113, 1-й эт. к.10
e-mail: grlan@jinr.ru тел. 21-65862 2

РОССИЙСКАЯ ФЕДЕРА

ПАТЕНТ

НА ИЗОБРЕТЕНИЕ

№ 2510488

УСТРОЙСТВО ДЛЯ ИЗМЕРЕНИЯ УГЛА

Патентообладатель(ли): *Объединенный Институт Исследований (RU)*

Автор(ы): *Будагов Юлиан Арамович (RU), Лябл Васильевич (RU)*

Заявка № 2012122383
Приоритет изобретения 30 мая 201
Зарегистрировано в Государственн изобретений Российской Федерац
Срок действия патента истекает 3

Руководитель Федера по интеллектуальной

Б.П. Симонов

Dzhelepov Laboratory of Nuclear Problems

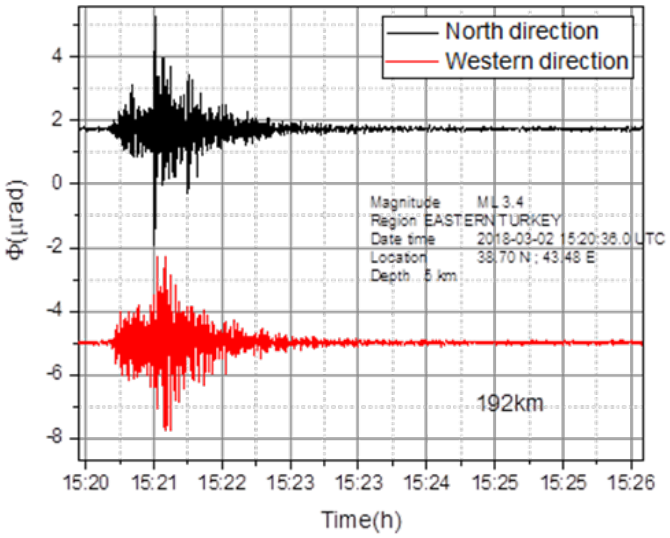
Project “Presicion laser metrology for accelerators and detector complexes”

Monitoring of angular microseismic oscillations of the Earth to determine the possibilities of stabilization of elements of colliders NICA, LHC, etc.

Increasing sensitivity of the VIRGO gravity antenna using data from inclinometers

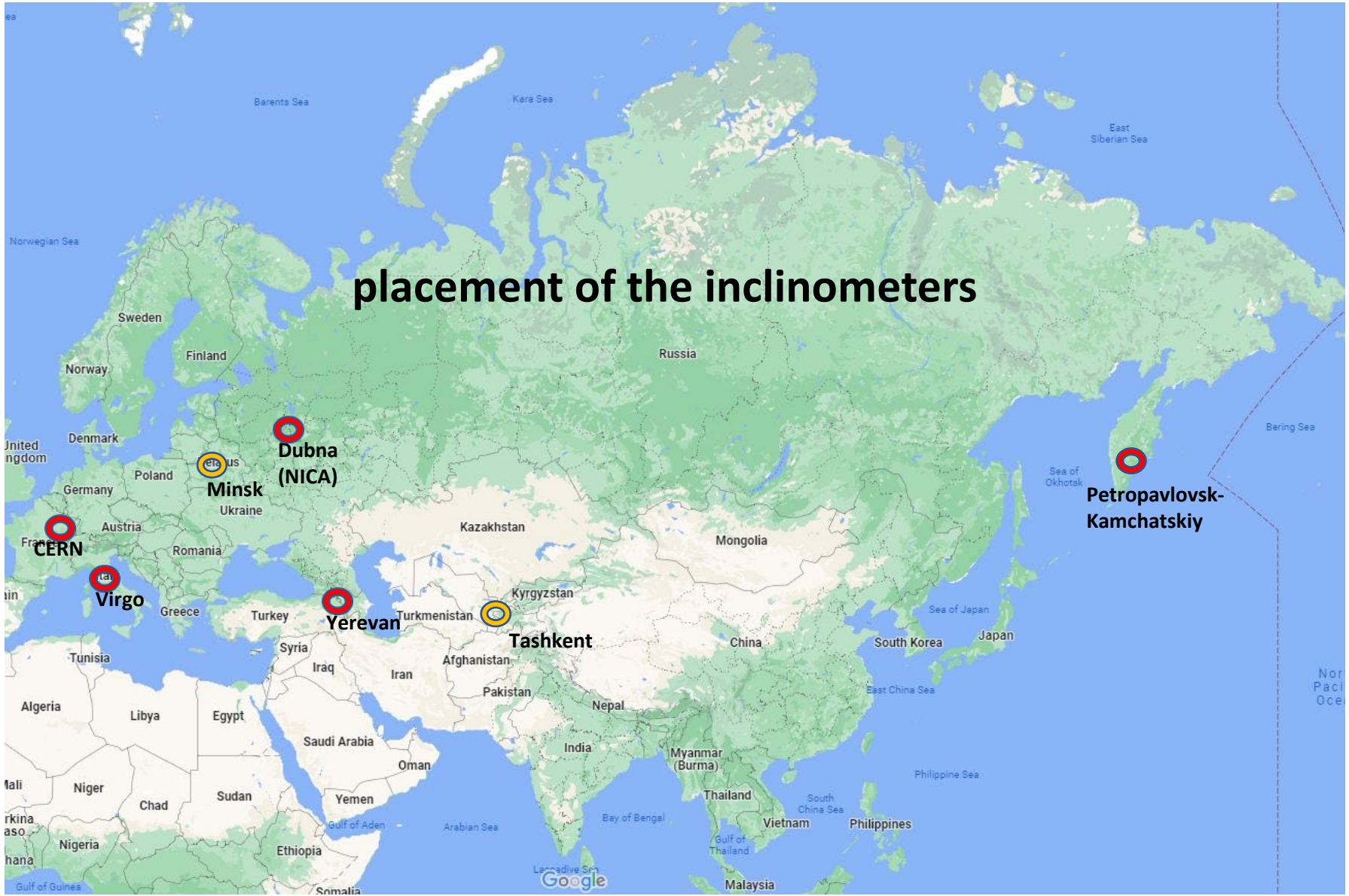
VIRGO gravitational antenna - 2 PLIs have been operating for more than 1 year.
Two PLIs are used in the noise reduction system of the North Mirror of the IGA VIRGO.

Creation of a software and hardware complex based on PLI for earthquake prediction



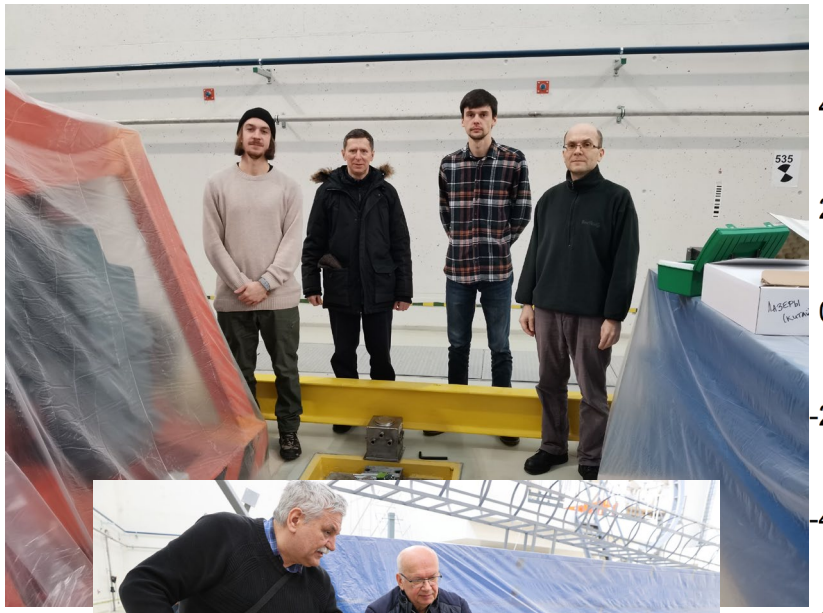
Dzhelepov Laboratory of Nuclear Problems

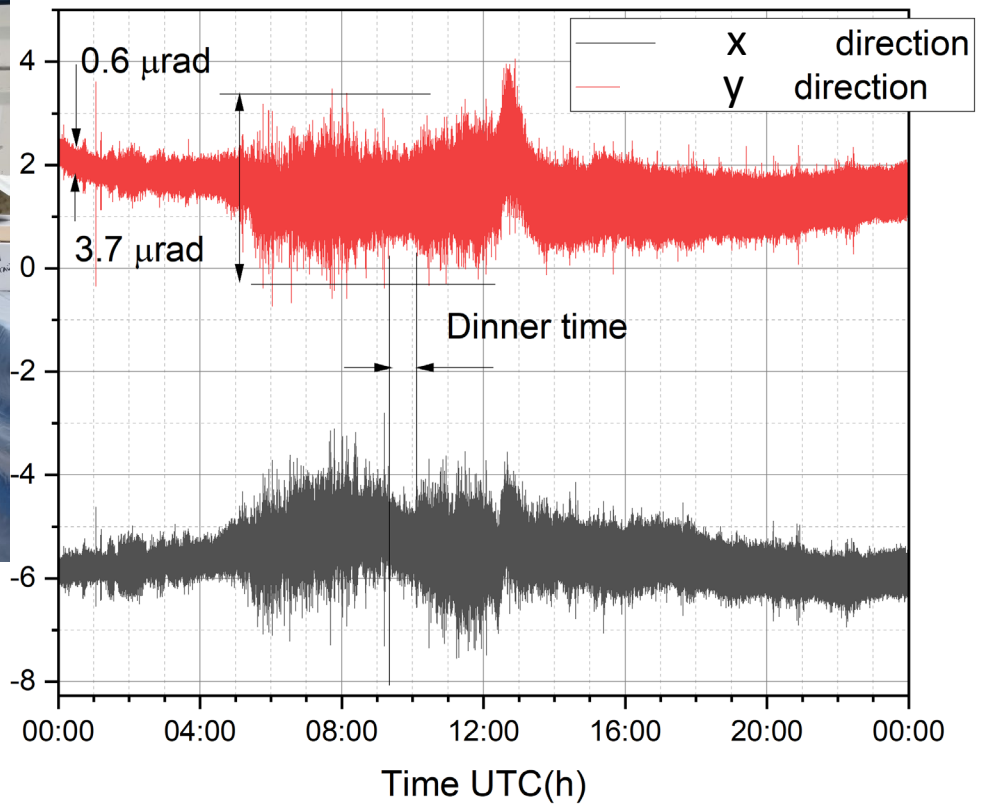
Project “Presicion laser metrology for accelerators and detector complexes”

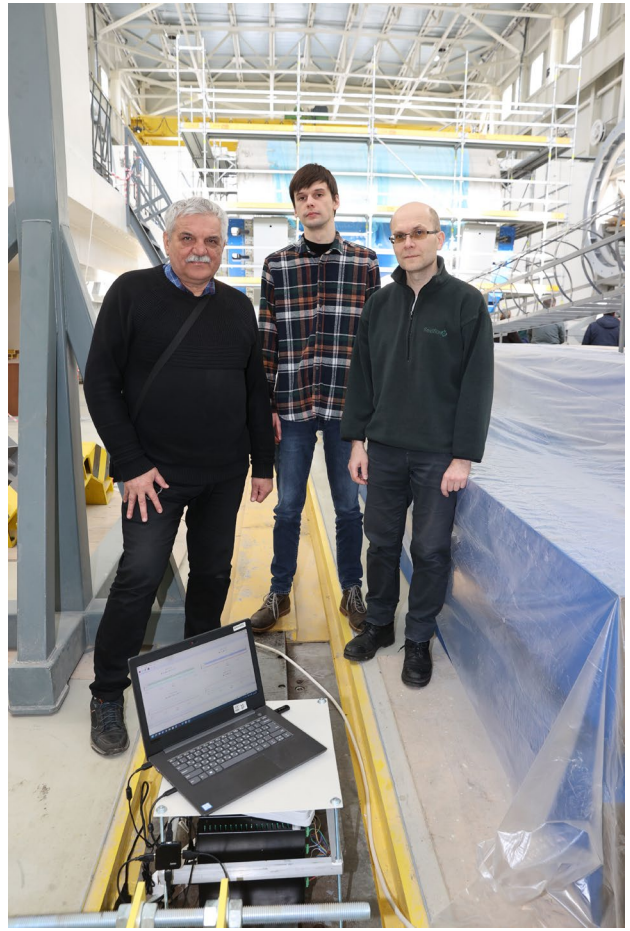


Angular microseismic activity monitoring in the MPD hall of the NICA collider

- **Two Compact Precision Laser Inclinometers (CPLI) were installed in the MPD hall in spring 2022.**
- **Data on microseismic activity of an industrial nature have been obtained, and the amplitudes of the angles of floor oscillations in the MPD hall have been determined.**
- **Monitoring of oscillations of the MPD hall base and supports of the magneto-optical elements of the NICA collider will be continued with the installation of additional MPLs.**
- **In the future, the largest microseismic noises sources will be defined and the compensating feedbacks are going to be implemented for the accelerator elements to stabilize the beam orbits and the region of their interactions.**







Using CPLI for Long-Term Earthquake Prediction

- **In Armenia, the International Geophysical Center "Garni Geophysical Observatory" hosts two PLIs. Angular microseismic activity is being monitored in the Armenian Highlands. In 2022, it is planned to modernize one MPLI and in subsequent years to create a network of several CPLIs in order to determine the zones of accumulation of seismic energy and predict earthquakes.**
- **An agreement was signed between JINR and the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan on the creation of a network of several CPLIs for long-term monitoring of changes in the Earth's surface for earthquake prediction.**
- **JINR signed an agreement with the Kamchatka Branch of the Federal Research Center "Unified Geophysical Service of the Russian Academy of Sciences" and Kamchatka State University named after V.I. Vitus Bering on the start of work on forecasting earthquakes and volcanic activity on the Kamchatka Peninsula. Delivery of CPLI to Kamchatka and joint monitoring activities are planned.**
- **JINR is planning common works with the Center for Geophysical Monitoring of the National Academy of Sciences of the Republic of Belarus on monitoring microseismic activity on the territory of the Republic of Belarus.**

Dzhelepov Laboratory of Nuclear Problems

Project “Presicion laser metrology for accelerators and detector complexes”

COLLABORATION AGREEMENT

CONCERNING

THE DEVELOPMENT OF A SEISMIC ACTIVITY MONITORING SYSTEM WITH THE PRECISION LASER INCLINOMETER FOR THE ADVANCED VIRGO EXPERIMENT

REFERENCE KR4469/ATS/HL-LHC
(THE “AGREEMENT”)

BETWEEN: THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (“CERN”), an Intergovernmental Organization having its seat at Geneva, Switzerland, duly represented by Fabiola Gianotti, Director-General,

AND: THE JOINT INSTITUTE FOR NUCLEAR RESEARCH (“JINR”), an Intergovernmental Organization having its seat at Dubna, Russia, duly represented by Victor Matveev, Director-General,

AND: THE ISTITUTO NAZIONALE DI FISICA NUCLEARE (“INFN”), an Italian agency dedicated to fundamental research, established in Rome, Italy, duly represented by Antonio Zoccoli, President,

Hereinafter each individually referred to as a

CONSIDERING:

УТВЕРЖДАЮ
[М.п.]
Директор Объединенного института ядерных исследований
«_____» 27 МАР 2019 20 г.

УТВЕРЖДАЮ
[М.п.]
Директор Института геофизики и инженерной сейсмологии им.А.Назарова
«_____» _____ 20 г.

ПРОТОКОЛ № 4869-2-19/23

о выполнении совместной научно-исследовательской работы Объединенный институт ядерных исследований и Институт геофизики и инженерной сейсмологии им. А.Назарова НАН РА, г. Гюмри, Республика Армения подписали настоящий протокол в целях

объединения усилий и сокращения сроков достижения научно-технических результатов в исследованиях и разработках в области ***изучения геодинамических процессов на территории Армении с целью выявления возможных зон возникновения сильных землетрясений и их прогноза,***

в соответствии с планами научно-исследовательских работ сотрудничающих организаций.

1.Совместные исследования и разработки стороны обязуются проводить по согласованной программе в рамках тем:

ботки систем ускорителей и коллайдеров
)-1127 2016/2023 и
ии, Геодинамика и Геофизическое прибор
аний и разработок

Утверждаю
Директор ОИЯИ
_____ Г.В. Трубников
«__»_____2022 г.

Утверждаю
Директор КФ ФИЦ ЕГС РАН
_____ Д. В. Чебров
«__»_____2022 г.

Утверждаю
И. о. ректора ФГБОУ ВО
КамГУ им.В. Беринга
_____ Е. С. Меркулов
«__»_____2022 г.

Договор о научно-техническом сотрудничестве между Объединенным институтом ядерных исследований (ОИЯИ), Камчатским филиалом Федерального исследовательского центра «Единая геофизическая служба РАН» (КФ ФИЦ ЕГС РАН) и Камчатским Государственным университетом им. Витуса Беринга (КамГУ им Витуса Беринга)

Международная межправительственная организация Объединенный институт ядерных исследований (ОИЯИ) в лице директора Трубникова Григория Владимировича, действующего на основании Устава, Камчатский филиал Федерального государственного бюджетного учреждения науки Федерального исследовательского центра «Единая геофизическая служба Российской академии наук» (КФ ФИЦ ЕГС РАН) в лице директора Чеброва Данилы Викторовича, действующего на основания Положения о КФ ФИЦ ЕГС РАН и доверенности от 19.07.2019 г. № 19 и Федеральное государственное бюджетное образовательное учреждение высшего образования «Камчатский государственный ... им. Витуса Беринга) в лице и.о. ректора Меркулова Евгения

«УТВЕРЖДАЮ»
Директор Института сейсмологии имени Г.А. Мавлянова АН Республики Узбекистан
_____ В.А. Рафиков
«____» _____ 2022 г.

«УТВЕРЖДАЮ»
Директор Объединенного института ядерных исследований
_____ Г.В. Трубников
«_____» _____ 2022 г.

ПРОГРАММА

Научной стажировки сотрудника Института сейсмологии АН Республики Узбекистан (ИС АН РУз) в Объединеный институт ядерных исследований (г.Дубна, Россия)

1. Наименование программы: Работы по проекту применения инклинометров, разработанных в ОИЯИ, для определения сейсмоопасных регионов.

2. Цель научной стажировки: Освоение наладки и обслуживания Малогабаритного Прецизионного Лазерного Инклинометра (МПЛИ).

НАЦЫЯНАЛЬНАЯ АКАДЭМІЯ НАВУК БЕЛАРУСІ
АДДЗЯЛЕННЕ ФІЗІКІ, МАТЭМАТЫКІ І ІНФАРМАТЫКІ

NATIONAL ACADEMY OF SCIENCES OF BELARUS
DEPARTMENT OF PHYSICS, MATHEMATICS AND INFORMATICS

220072, Беларусь, г.Мінск, пр. Незалежнасці, 66, к. 225. АФМІ НАН Беларусі
тэл. 325 83 76, факс (017) 325 83 76, E-mail: physics @ presidium. bas-net. by

18.08.2022 № 25/17

Директору Объединенного института ядерных исследований
академику РАН
Трубникову Г.В.

Глубокоуважаемый Григорий Владимирович!

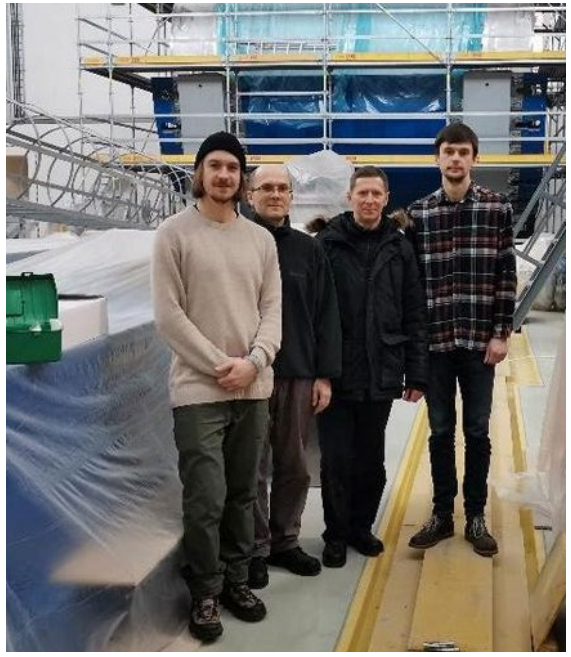
По результатам рабочей встречи с 6 по 8 июня 2022 года представителей Центра геофизического мониторинга НАН Беларуси с сотрудниками Лаборатории ядерных проблем им. В.П.Джелепова Объединенного института ядерных исследований г.Дубна (Российская Федерация) подготовлен проект на проведение научно-исследовательской работы по теме: «Исследовать разрешающие способности малогабаритного прецизионного лазерного инклинометра (МПЛИ) в регистрации сейсмических событий и угловых колебаний поверхности Земли в системе сейсмологического мониторинга Беларуси» (2023-2024 гг.).

Project “Presicion laser metrology for accelerators and detector complexes”

FTE **12** Young colleagues **6**

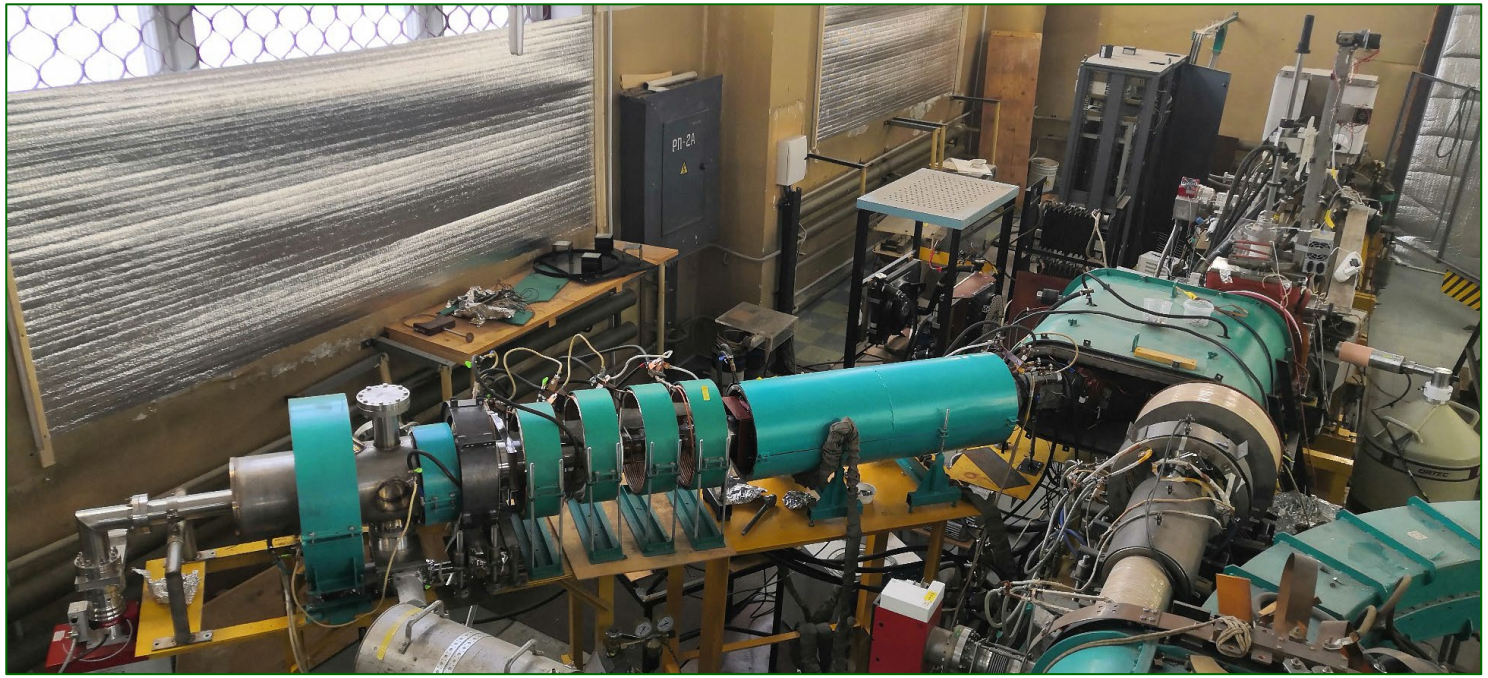
Estimated cost, kUSD

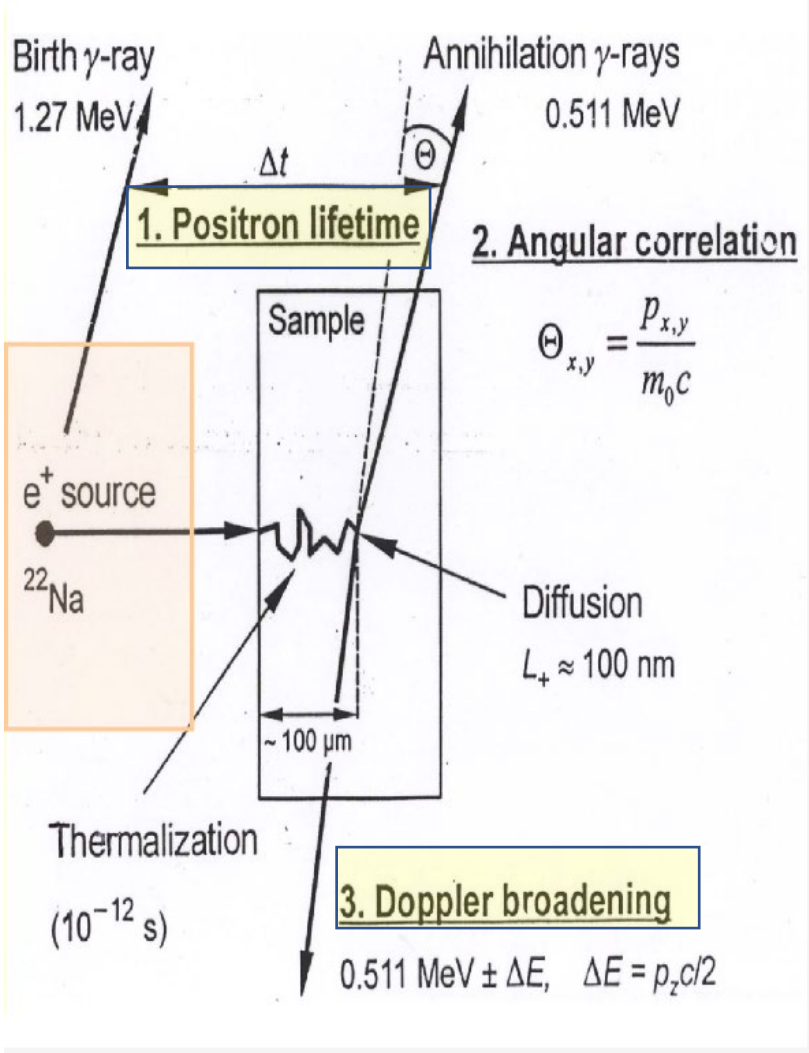
2024	2025	2026	2027	2028	2029	2030	Total
100	100	100	100	100	100	100	700


Dzhelepov Laboratory of Nuclear Problems

Project "Development of experimental techniques and applied research with slow monochromatic positron beams (PAS)"





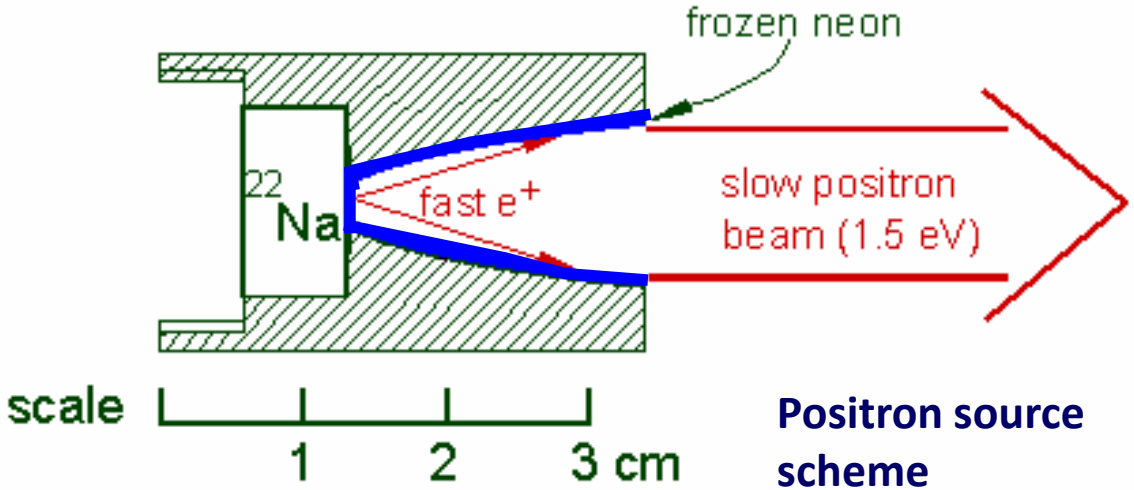
Leader: Sidorin A. A.

Scientific Leader: akademitian Meshkov I. N.

Formation of slow positron flow

The most efficient and convenient radioactive isotope 22Na was chosen as a source of positrons. The half-life of the isotope is 2.6 years, which makes it suitable for long-term experiments. This isotope gives a relatively high positron yield of ~ 90.5% of decays. In addition, the technology of its manufacture is well developed, which ultimately affects the price of the isotope. A source manufactured by iThemba LABS (Cape Town, RSA) is used.

Solid neon was chosen as the moderator of positrons - one of the most effective moderators.

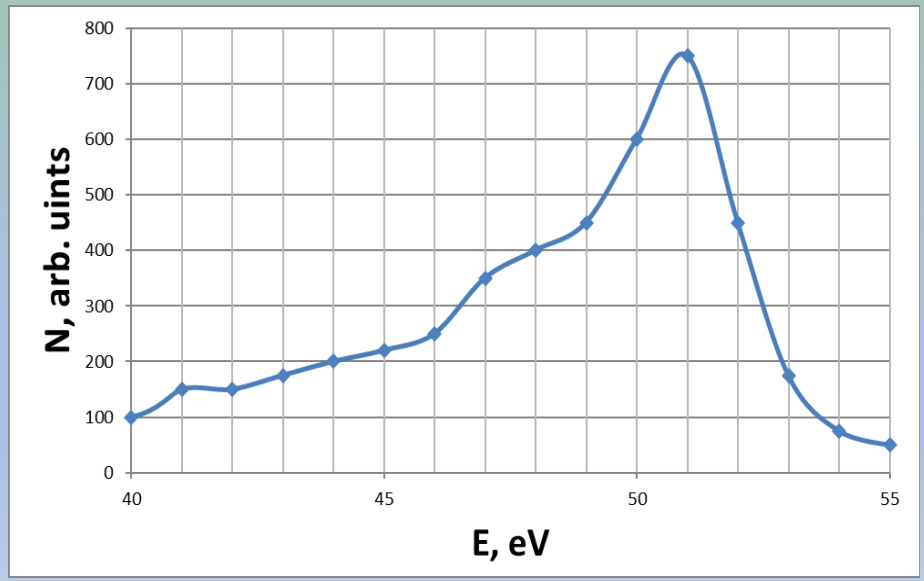


Positron source scheme

Cryogenic source of slow monochromatic positrons

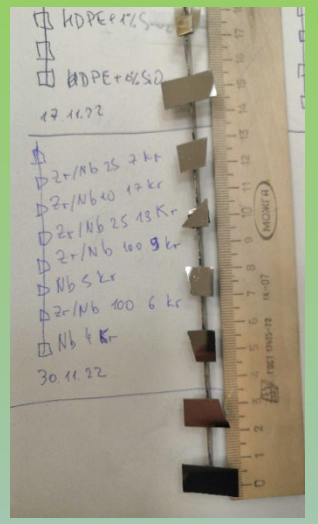
In November 2016, a cryogenic source of slow monochromatic positrons based on a cryocooler was put into operation. The closed loop helium system allowed to solve the problem of limited operating time due to lack of the liquid helium. Also, this scheme made it possible to reduce the source preparation time from 6-7 hours to 3 hours.

Typical slow positron spectrum from a cryogenic source of slow monochromatic positrons. Full width at a half magnitude is of 2 eV. The output of positrons is 3.3×10^6 positrons per second.



Measurement Equipment for the Doppler Broadening of the Annihilation Line (DUAL) Method

The test samples are placed on a holder, which is placed on a movable insulated vacuum inlet into the vacuum chamber on the axis of the direct flow of positrons from a cryogenic source of slow monochromatic positrons. An adjustable negative potential of up to 35 kV is applied to the samples.



Holder and vacuum inlet

Annihilation gamma quanta are detected by the HpGe detector of the company Ortec, which at a quantum energy of 511 keV has a resolution of 1.2 keV. The detector signal is amplified and sent to a multichannel analyzer connected to a computer, where the spectrum of the annihilation process is formed.

HpGe detector and control electronics unit

The PALS method on the monochromatic positron flow

Along with the DUAL method, the PALS method is also developed by the classical scheme. PALS spectroscopy is performed on positrons of a standalone 22Na source. This isotope emits in 3.3 ps after positron emission a gamma quantum of an energy of 1274 keV, which is used as the "Start" signal of the spectrometer to measure the lifetime. The "Stop" signal is the registration of coincidences of two annihilation gamma quanta with an energy of 511 keV (a channel with the formation of paraPositronium). The difference in the time of registration of the first and second signals gives the value of the positron lifetime. The disadvantage of the classical PALS method is the wide range of positron energies from the source and the difficulty of determining the depth of the detected defects. To do this, it is necessary to reduce the thickness of the sample in layers, repeating the measurements each time.

1 – sample and two photomultiplier
2 – lifetime spectrometer
3 – voltage source
4 – PC

The disadvantages of classical PALS can be solved by creating an ordered flow of monochromatic positrons. Monochromatizating is described above. Ordering occurs when positrons pass through a resonator (U_{RF}, Fig.1.) to which a pulsed high-frequency voltage of special shape is applied. Then the positrons are accelerated in a static electric field (U_A, Fig.1.) and get the target. Due to special shape U_{RF} positrons come to the sample at the same time.

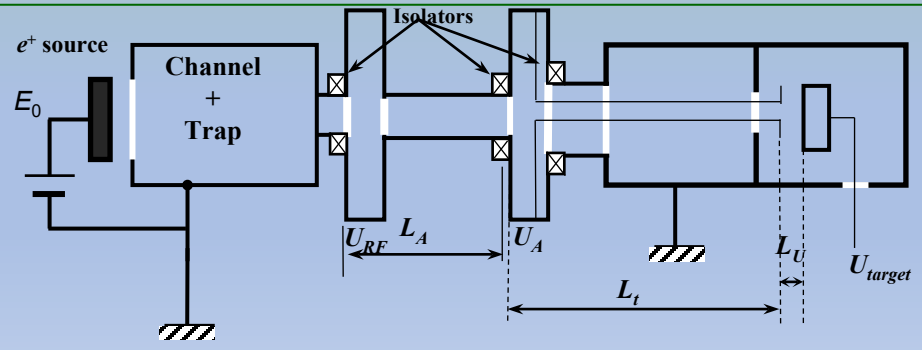
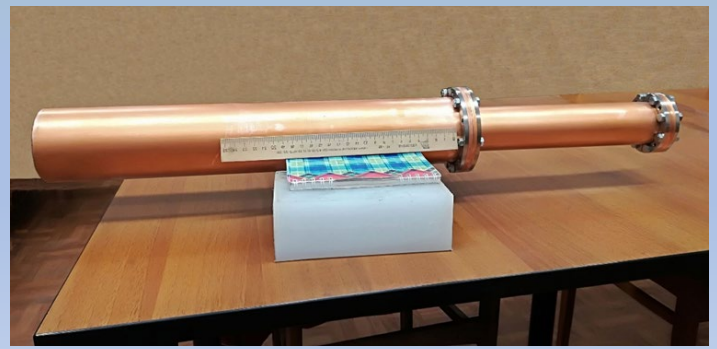


Fig.1. Scheme of the channel for the formation of an ordered positron flow



The special resonator is assembled and installed in a vacuum chamber to obtain more monochromatic positron spectra.

Sample preparation

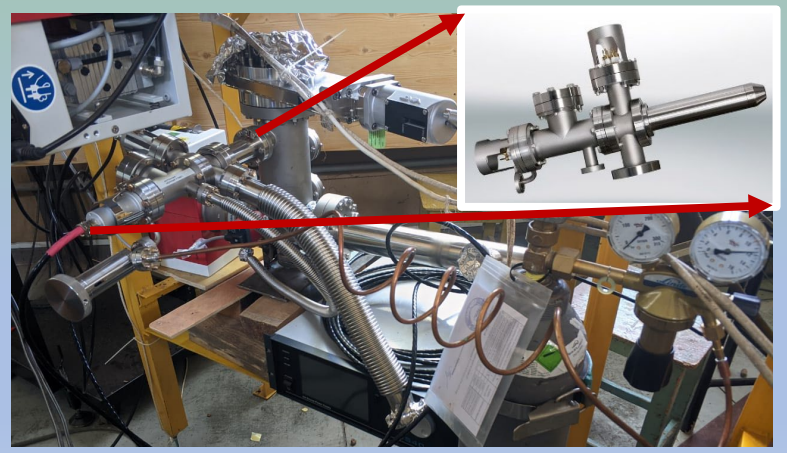
We have several devices to prepare samples in various ways:

Vacuum oven 1000 degrees Celsius for sample annealing

Press

Sandblasting

Studies of thin-layer or multilayer samples can be effectively carried out using reactive ion etching.



Ion source

Consumers

Sector research

Analysis of physical properties of metals and compounds W, WC, WC+6%Co, WC+10%Co under the action of ionizing radiation. Investigation of defects caused by ionizing radiation, investigation of changes in structure and surface by various spectroscopic methods.

LNP

Polymer nanocomposites are perspective materials for use in intelligent microelectronic devices, capacitors, high-voltage electrical insulation, etc.

Tomsk Polytechnic University (Tomsk)

In nuclear power and space exploration, there are problems associated with the effect of radiation on structural materials and with a reduction in their service life. To solve these problems, scientists propose to use a coating of zirconium and niobium nanolayers.

M. V. Lomonosov NARFU (Arkhangelsk)

Currently, diamonds are widely used in science and technology. However, the properties of diamond due to its defects have not been fully studied. In addition to optical methods, positron annihilation spectroscopy (PAS) can be successfully used to study defects in diamonds. Positrons can detect vacancies, small and large clusters of vacancies induced by irradiation, providing information about their size, concentration and chemical environment.

Rzhanov Institute of Semiconductor Physics Siberian Branch of Russian Academy of Sciences (Novosibirsk)

The development of photonic devices based on GeSiSn materials compatible with silicon technology in the infrared range of about 2 microns and above opens the possibility of using these devices in such areas as sensorics (gas and biological sensors), biomedical diagnostics and environmental monitoring, as well as astrophysics.

Publications

A far from complete list of articles in the framework of the project:

Journal: Materials
Title: Investigation of Nitrogen and Vacancy Defects in Synthetic Diamond Plates by Positron Annihilation Spectroscopy (in print)

Journal: Crystals
Title: Detection of defects in synthetic diamond plates by positron annihilation spectroscopy method

Journal: Coatings
Title: The Microstructure of Zr/Nb Nanoscale Multilayer Coatings Irradiated with Helium Ions

Journal: Journal of Applied Physics
Title: Point defect creation by proton and carbon irradiation of α-Ga2O3

Journal: Acta Metallurgica Sinica (English Letters)
Title: Surface and Subsurface Defects Studies of Dental Alloys Exposed to Sandblasting

FTE 5,5 -> 8

A. Sidorin
Sector Leader

Young colleagues 3

I. Meshkov
Scientific Leader

Cost estimate (kUSD)

2024	2025	2026	2027	2028	2029	2030	**Total**
50	40	35	35	35	30	50	**275**

Dzhelepov Laboratory of Nuclear Problems

Project "Novel semiconductor detectors for fundamental and applied research"

G.A. Shelkov, V.A. Rozhkov

Conducting scientific and methodological studies of high-resolution hybrid matrix detectors for high energy physics and the atomic nucleus, as well as semiconductor detectors with increased radiation resistance

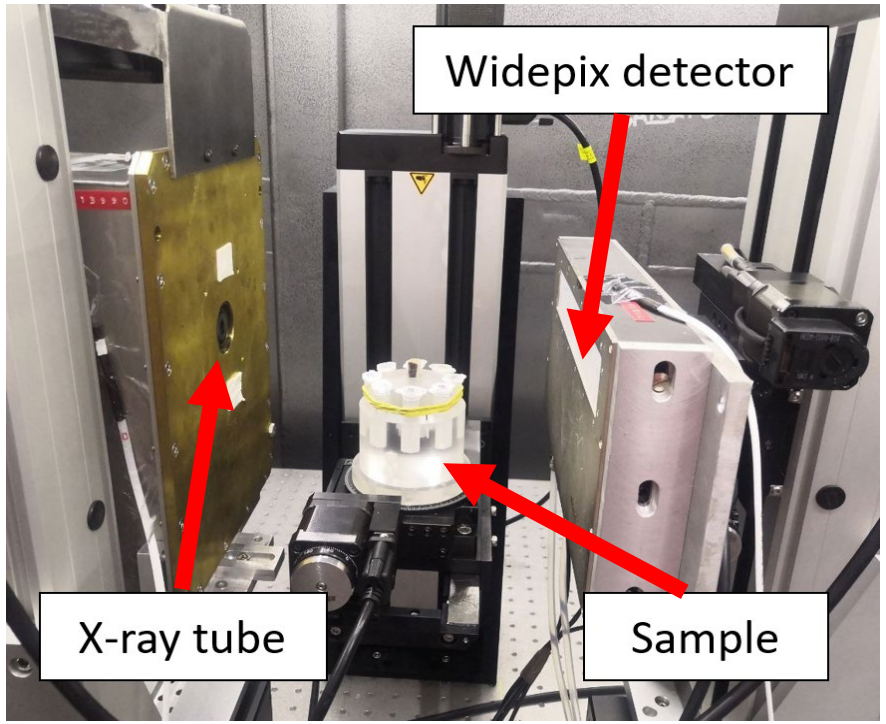
Development of scientific cooperation with research institutes to explore the possibility of application developed detectors in other fields of science and technology.

Development of infrastructure for studying the properties of semiconductor detectors, including tests on beam particles for use by JINR groups and institutes of the Member States.

One of the main goal is the creation of an independent detector for medical radiography and tomography, which has new capabilities for measuring the energy of each registered X-ray gamma-quantum.

Experimental Microtomograph “Kalan”

The prototype of an X-ray tomograph was created at DLNP

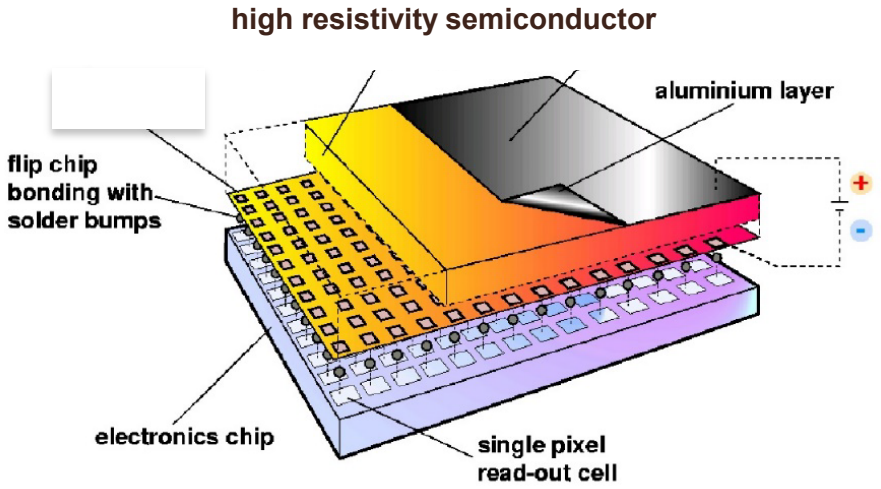


Widepix detector:

- 15 Medipix 3RX in one row
- 256x3840 pixels
- Size of pixel - 55x55 mkm
- Si sensor

The main advantage of hybrid pixel semiconductor detectors is the ability to identify substances on roentgenogram using its ability to measure the energy of recorded γ-quanta.

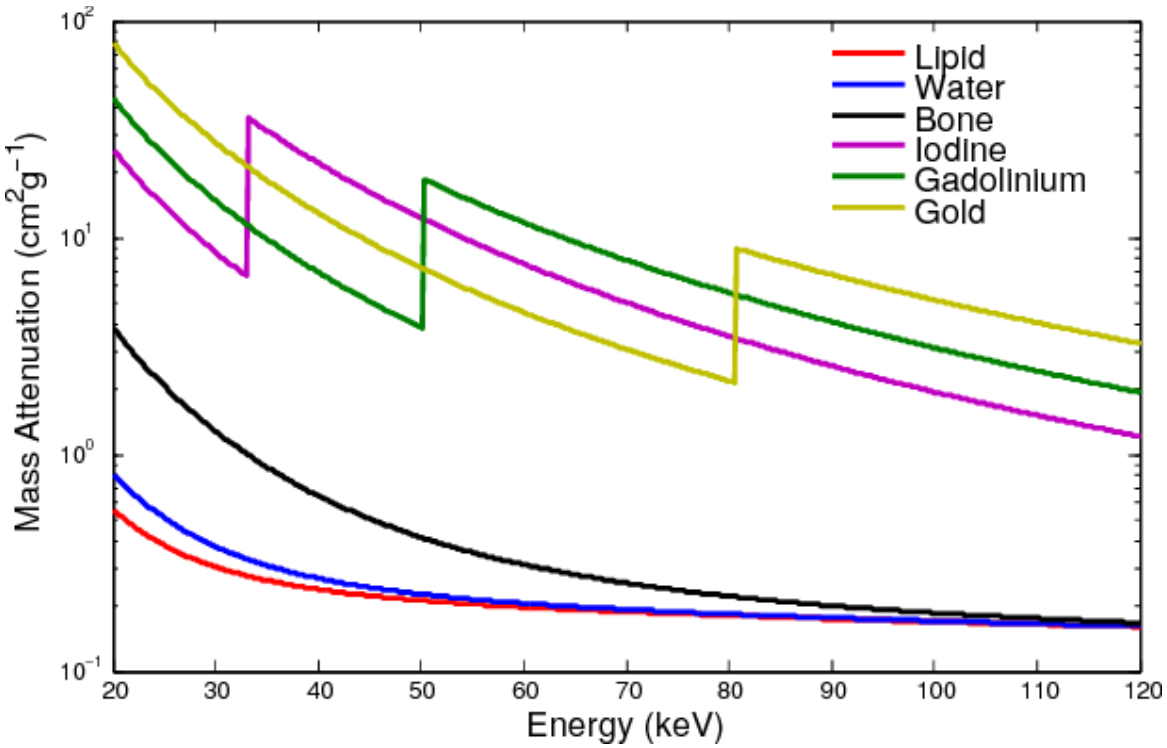
Hybrid pixel semiconductor detector sketch



$I = I_0 e^{(-\mu\rho x)}$

Identification substances by the behavior of the absorption cross section in the region of the K-line energy

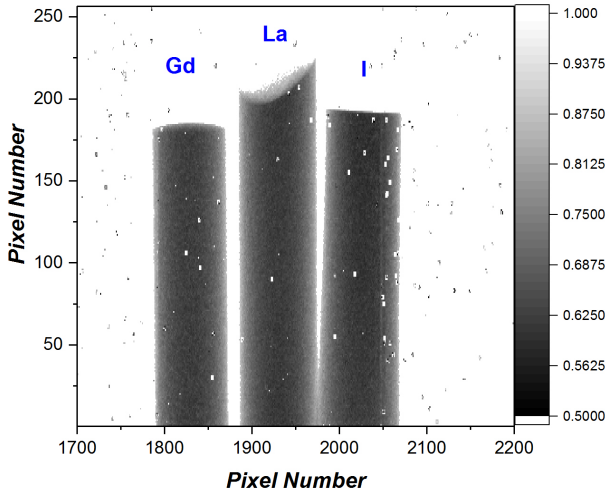
$\mu \sim C*Z^4/E^3$ - mass attenuation



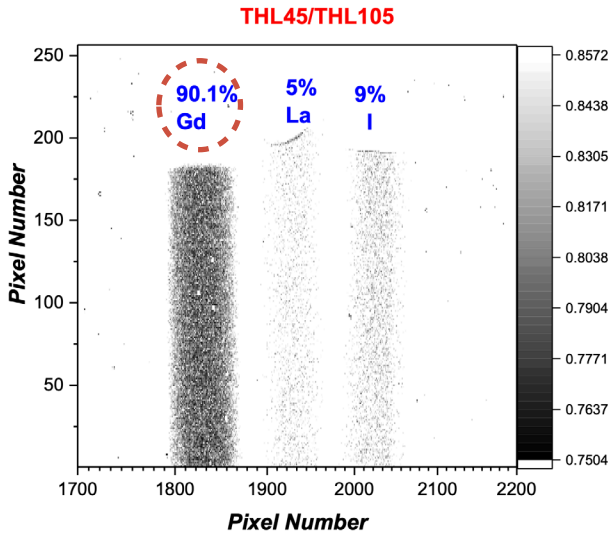
Identification of substances on 2D radiograms due to the energy information.

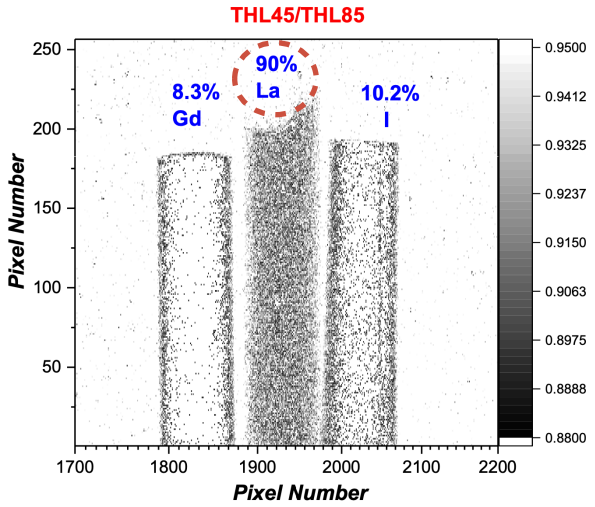
2D-rentgenogramm

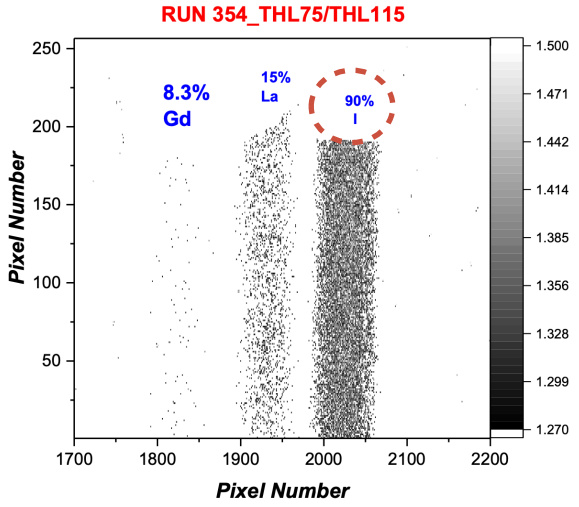
2D X-ray roentgenogram of three plastic tubes D = 5 mm with solutions of different substances. The concentration of the solutions was adjusted so that the absorption coefficients of X-ray in all samples were equal.



Same frame after application of three different pre-calibrated criteria for identification of sample materials - Gd, La and Iodine. The figures show the percentage of pixels selected by these criteria



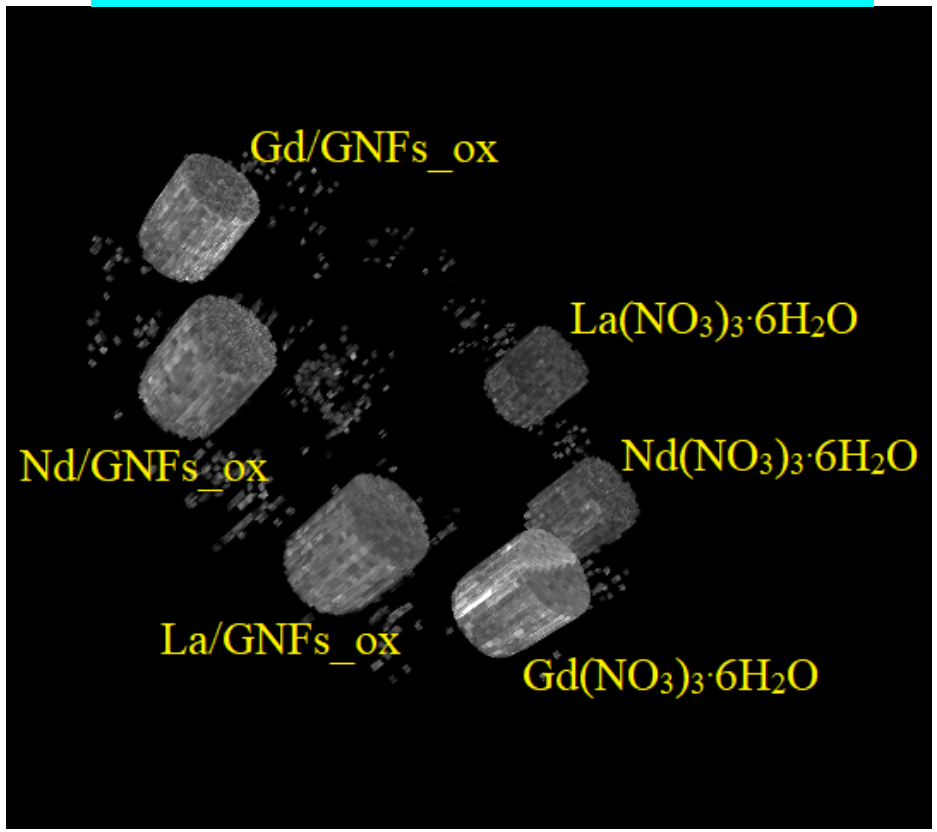




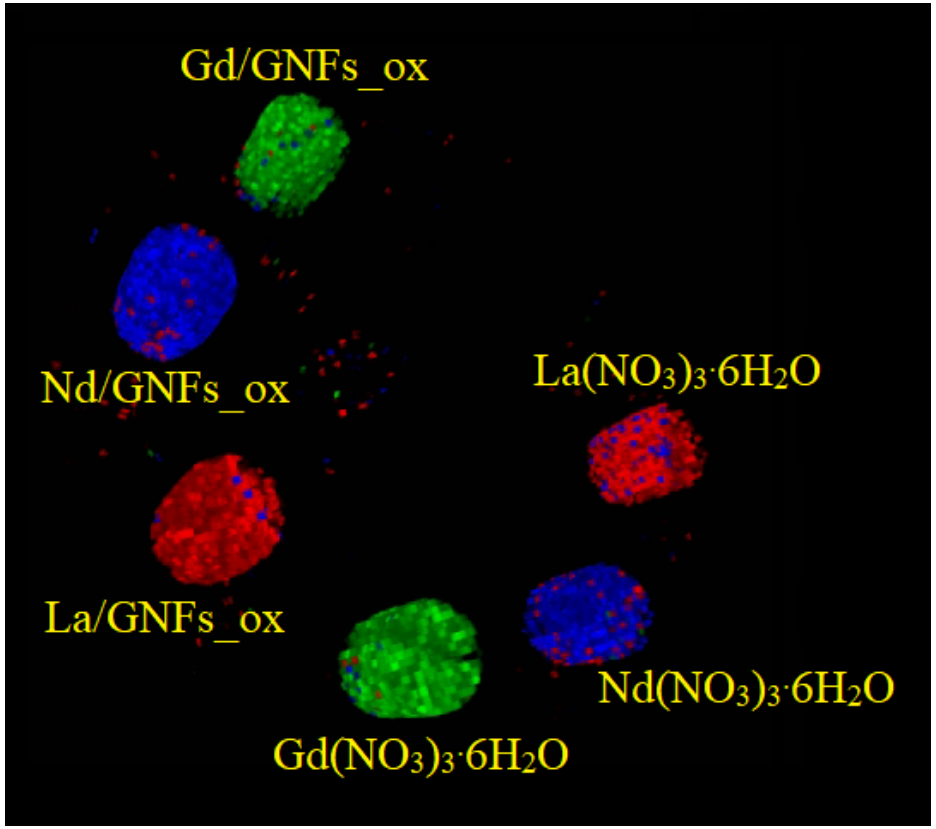
Identification of substances on 3D tomograms.

Reconstruction of 3D tomograms

Without the use of energy information



Using spectroscopic information



FTE 6,4 Young colleagues 3

Cost estimate (kUSD)

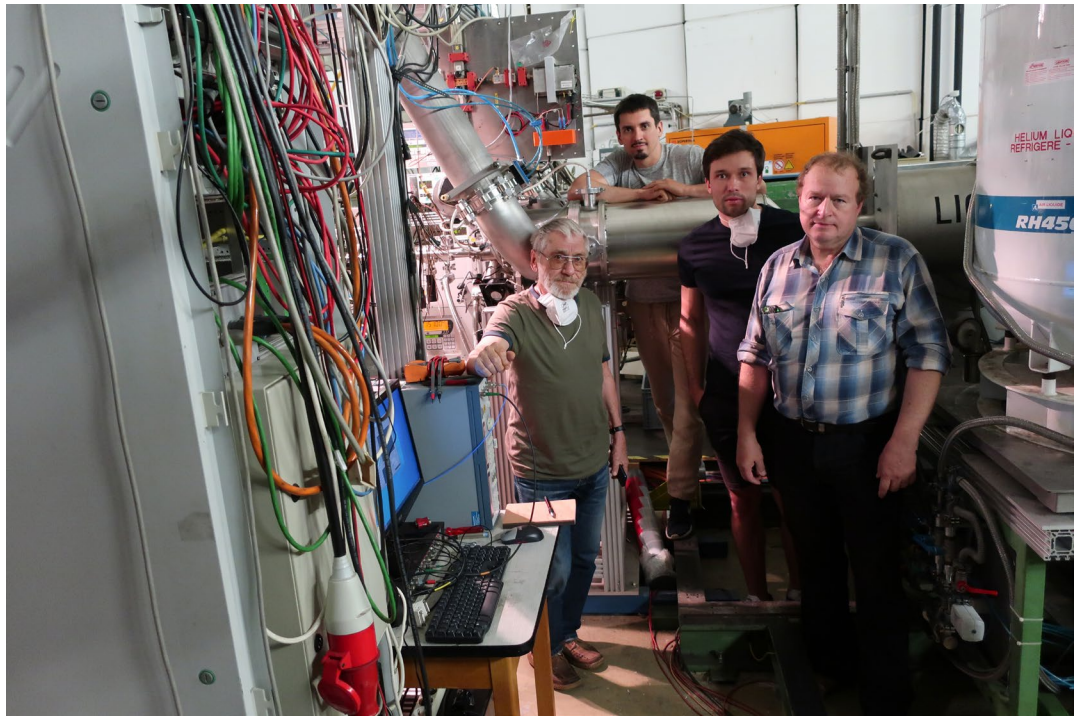
	2024	2025	2026	2027	2028	2029	2030	**Total**
Materials and equipment	130	110	100	80	80	60	60	**620**
Scientific trips	40	30	30	30	30	30	30	**220**
Sum	170	140	130	110	110	90	90	**840**

Yu. A. Usov

A Study of the Nucleon Spin Structure in Strong and Electromagnetic Interactions

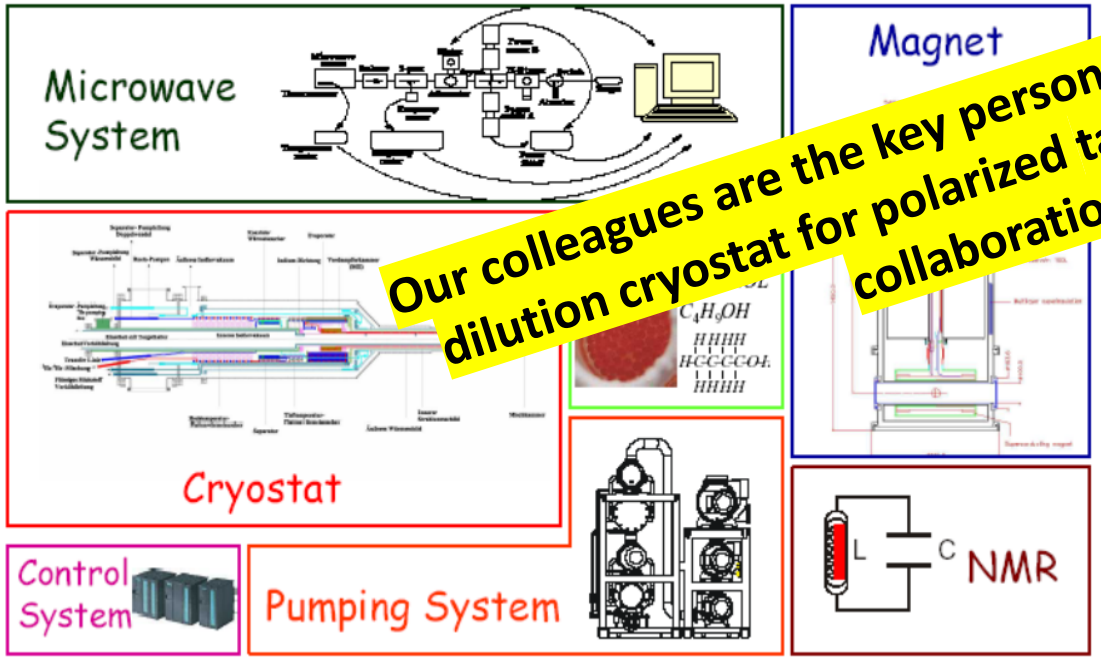
The Gerasimov Drell-Hearn, GDH, sum-rule for polarized photoproduction from a polarized nucleon within a polarized nuclear target.

$$\int_0^\infty \frac{d\nu}{\nu}\left[\sigma_{3/2}(\nu)-\sigma_{1/2}(\nu)\right]=\frac{2\pi^2\alpha}{m^2}\kappa^2$$

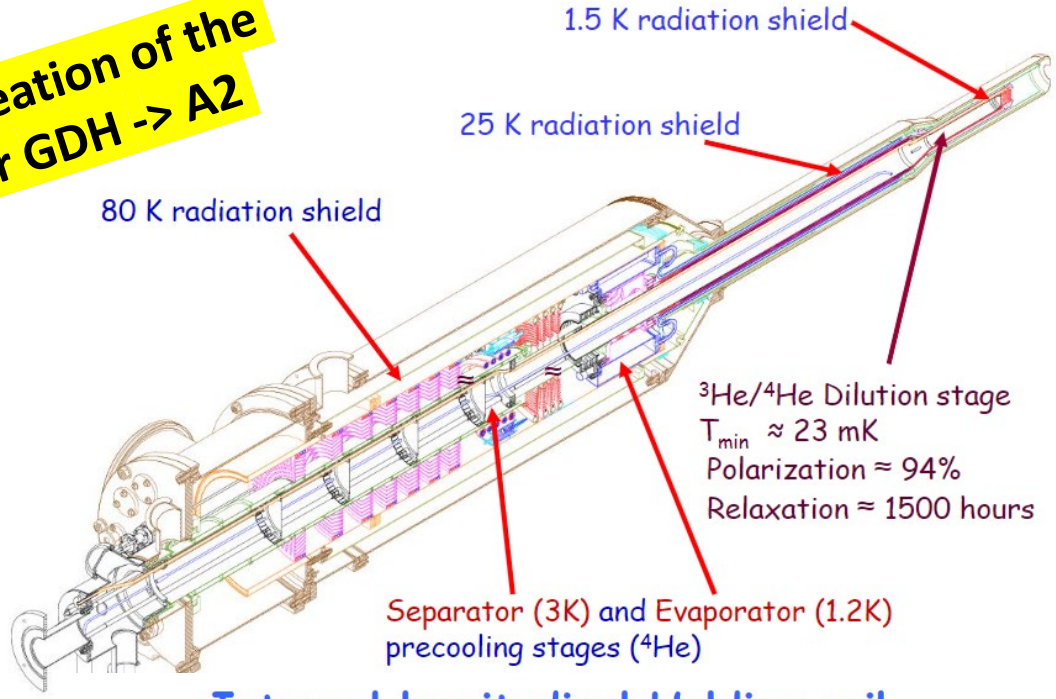


The GDH-Collaboration (A2) has chosen to perform the measurement of the integrand of the sum rule at two accelerators: Elsa in Bonn and Mami in Mainz, Germany. The measurements at Mami are dedicated to the lower energy part up to 800 MeV while, with an overlap, the measurements at Elsa address photon energies of 600 MeV through 3 GeV.

The Frozen Spin Target

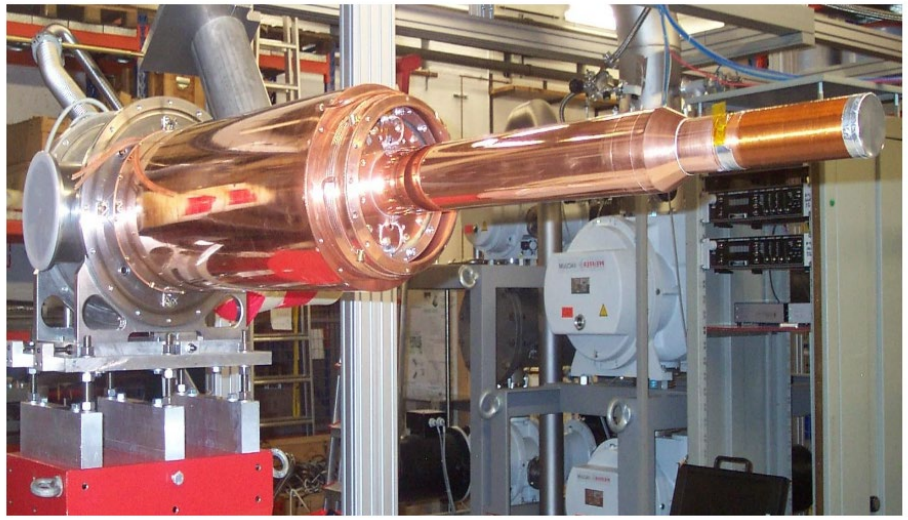


Our colleagues are the key persons for creation of the dilution cryostat for polarized target for GDH -> A2 collaboration



Internal longitudinal Holding coil

(solenoid coil manufactured of 0.227-μm multifilamental NbTi cable and consisting of four layers, each having 600 turns wound around a 0.3-mm thick copper holder, T ≈ 1.5 K)



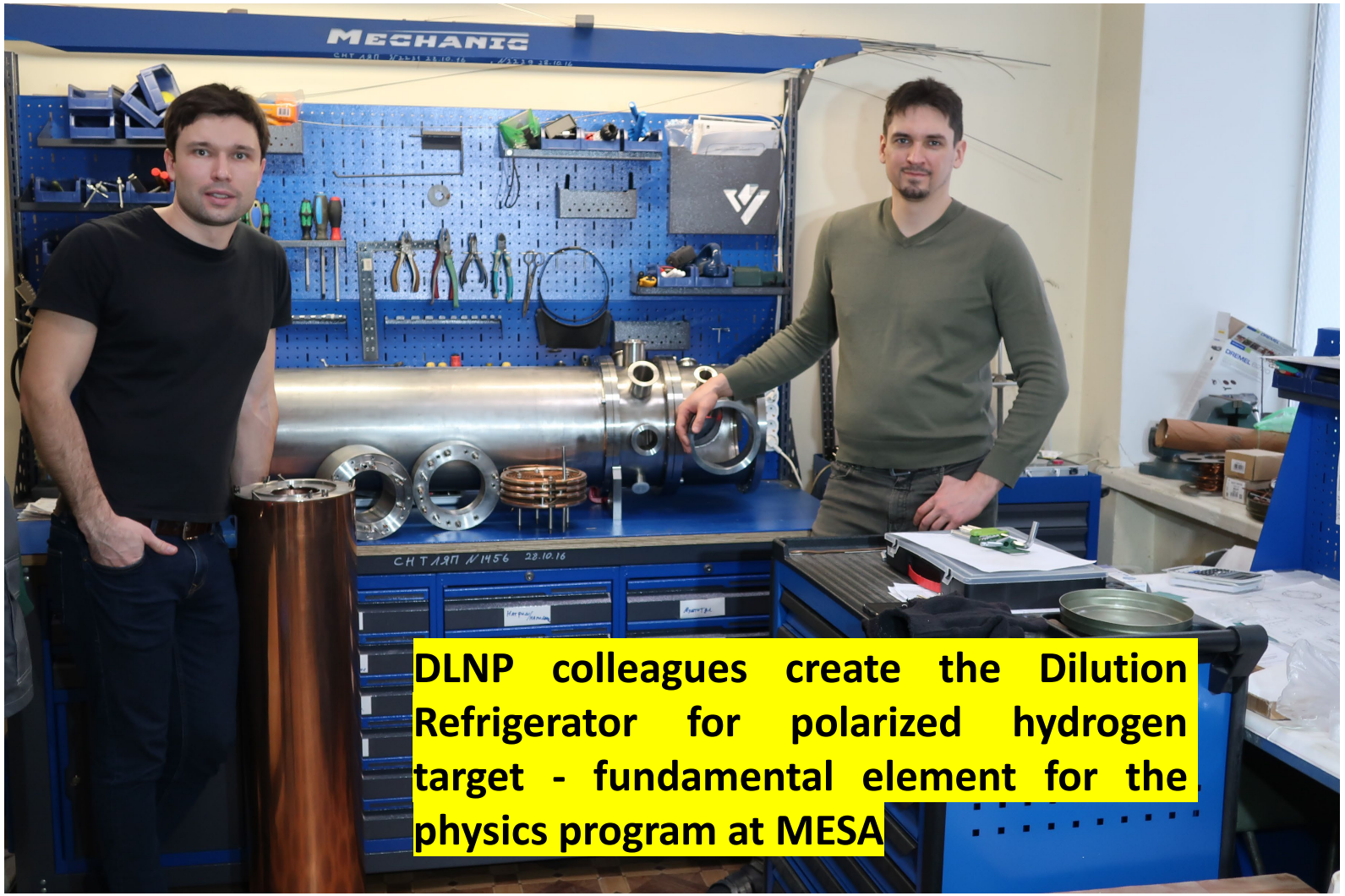
Main parameters

- **Working parameters of the dilution cryostat are in agreement with the technical requirements:**
  - **T_{min} ≈ 23 mK;**
  - **polarization relaxation time ≈ 1500 hours (at T=30 mK);**
  - **time to cool from room temperature ≈ 5 hours;**
  - **LHe consumption in the frozen spin mode ≈ 2 l/hour**
- **Internal holding coils provide longitudinal/ transverse field 0.4 Tesla at 30 A**
- **Any combinations of beam and target polarizations are possible**
- **Two-part insert makes the sample loading operation easy and convenient**

Research and development for polarization equipment for MESA accelerator

Energy-Recovery-Linac (ERL) accelerator technology, which enables very high electron-beam luminosities on internal targets at low energies. One of aims for the new electron accelerator MESA is to measure the weak mixing angle in electron-proton scattering with a precision of 0.13%. The beam polarization significantly contributes to this measurement. The Möller polarimeter proposed by V.Luppov and E.Chudakov opens the way to reach a sufficiently accurate determination of polarization. Research and development for polarization equipment for MESA is already started. At the moment the polarized atomic hydrogen target is under construction by Mainz-JINR team. The important parts of this "polarized atomic hydrogen target" is Dilution Refrigerator) where JINR (Sector of Low Temperature, DLNP) have a long-term experience. GSI Helmholtzzentrum asked DLNP to manufacturing (GSI – Purchase order # 4500189093) main parts of this Cryostat.

Here you can see any main part of this Dilution Refrigerator after production and tests at DLNP area.

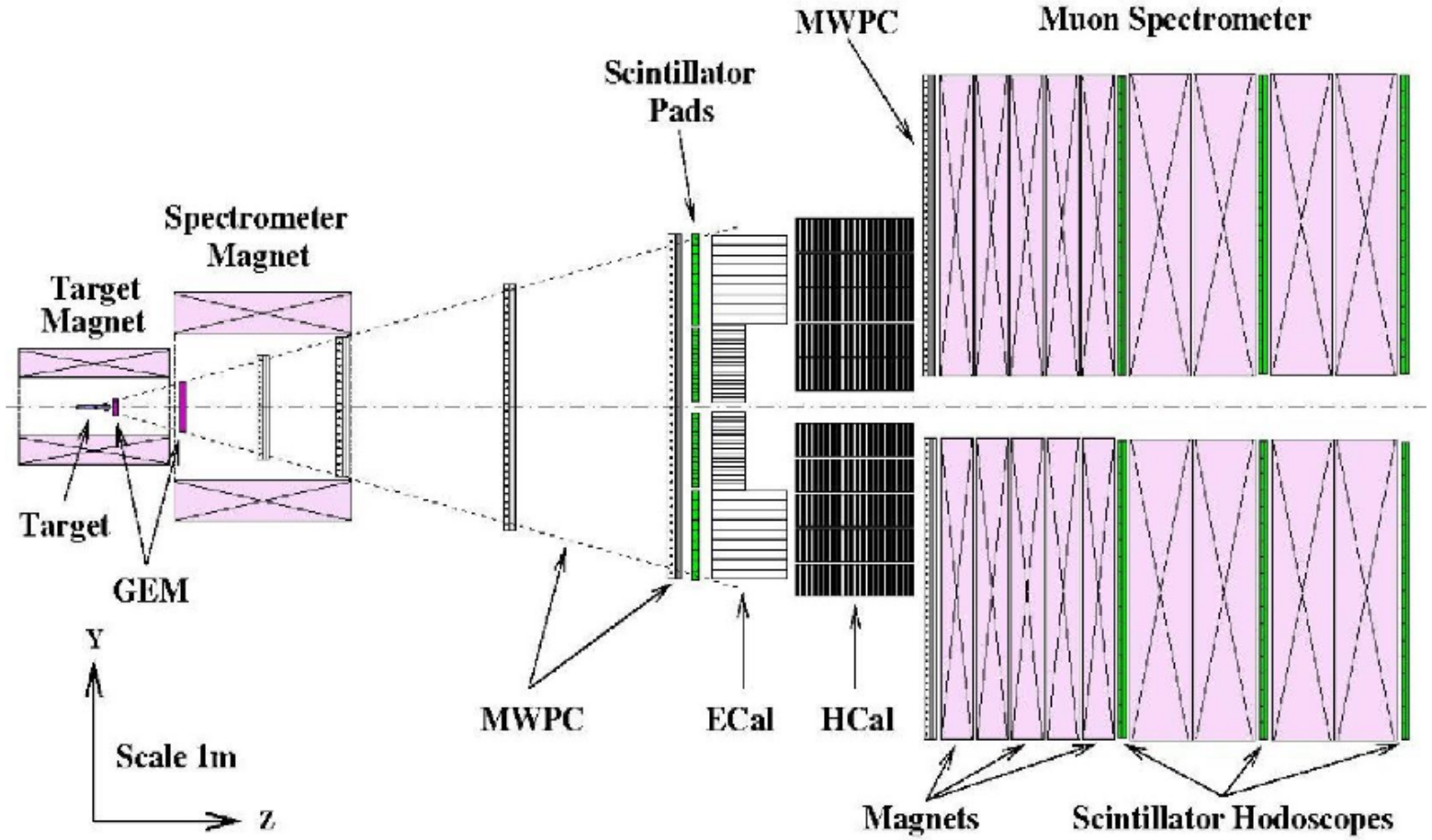


DLNP colleagues create the Dilution Refrigerator for polarized hydrogen target - fundamental element for the physics program at MESA

At the National Research Center "Kurchatov Institute" - IHEP, an experiment with a fixed target "SPASCHARM" is being prepared for the start of physical data acquisition to systematically study polarization phenomena in exclusive and inclusive hadronic reactions in the energy region of the U-70 accelerator in Protvino. The SPASCHARM universal facility will register dozens of different resonances and stable particles produced on a polarized proton target. Measurements are planned for various types of beams (π±, K±, p, p-bar). In parallel with the single-spin asymmetries A_N, the polarization of hyperons and the elements of the spin density matrix of vector mesons will be measured.

SPASCHARM experimental setup

The cryostat production for polarized proton target is the task for our colleagues



Dzhelepov Laboratory of Nuclear Problems

Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation 04-2-1132-2017/2023

Further development of methods, technologies, schedule modes and provision of radiotherapy

Development of methods and programs for creating cyclotron-type accelerators. Development and upgrade of cyclotrons for medical application

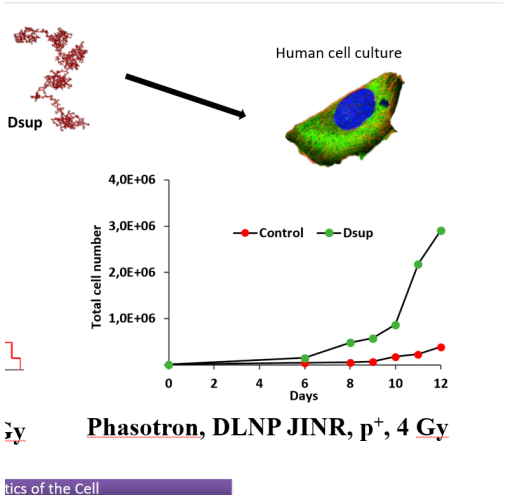
Study of the radioprotective properties of the Damage suppressor (Dsup) protein on a model organism D.melanogaster and the human cell culture HEK293

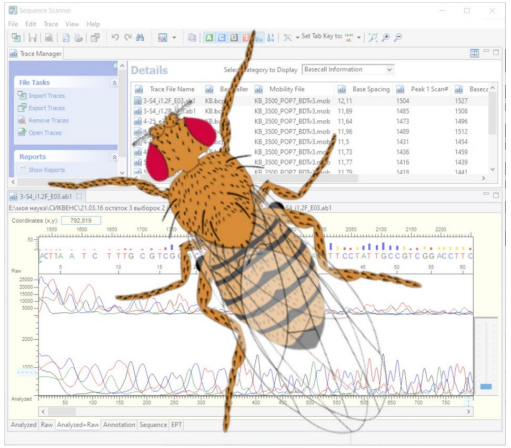
RADIOGENE: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in Drosophila melanogaster

Main parameters of MSC 230

- Low power consumption.
- Reasonable size.
- Minimum engineering efforts and challenges.
- High quality of the beam.

Magnet type	Compact, SC coil, warm yoke
Ion source	PIG
Final energy, MeV	230
Pole radius, mm	1080
Mean magn. field (center), T	1.7
Dimensions (height×width), m	1.7 × 3.9
Weight, tonnes	100
Hill/Valley gap, mm	50/700
A*Turn number	270 000
RF frequency, MHz	106.5
Harmonic number	4
Number of RF cavities	4
Voltage, center/extraction kV	40/100
RF power, kW	55
Number of turns	500
Beam intensity, μA	10
Extraction type	ESD



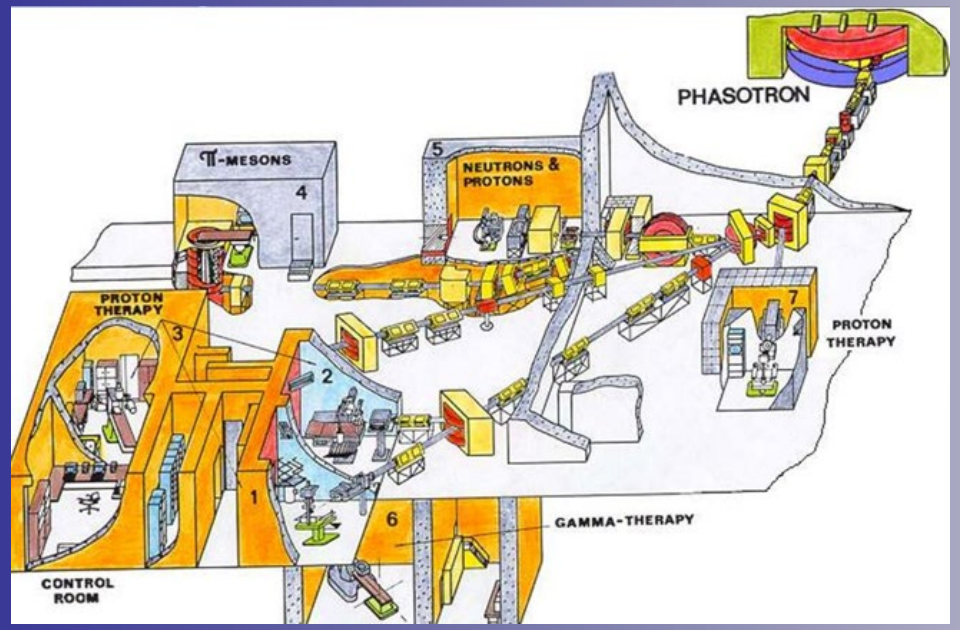


Dzhelepov Laboratory of Nuclear Problems

Project "Further development of methods, technologies, schedule modes and provision of radiotherapy "

G.V. Mitsyn S.L. Yakovenko

The main goal of the Project is realization of medical-biological and clinical investigations at the Medico-Technical Complex (MTC) based at the Phasotron of the DLNP, to study the effectiveness of hadron radiotherapy, modernization of the equipment and devices and development of new methods of radiotherapy and associated radiobiological accompaniment of cancer patients.



Milestones of activity:

1967 – the beginning of the research on proton therapy;

1968 –1974 – first 84 patients treated with protons;

1975 –1986 – upgrading of the accelerator and construction of a Medico-Technical Complex for hadron therapy;

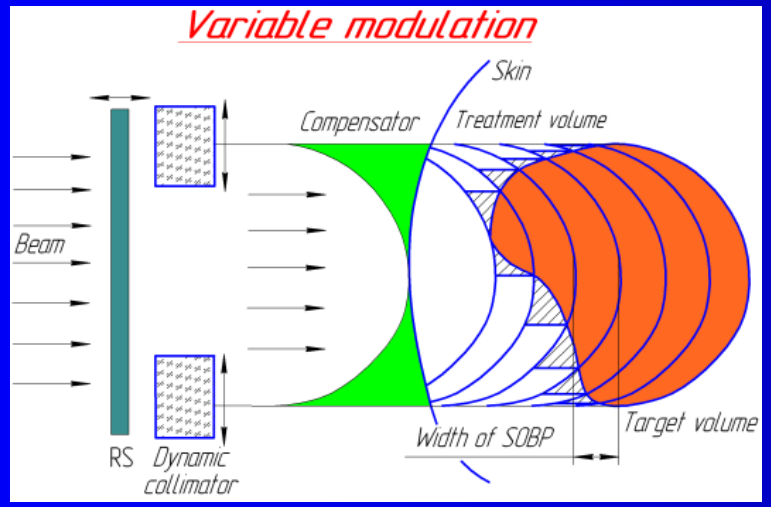
1987-1996 – treating of 40 patients with protons, mostly with uterine cervix cancer;

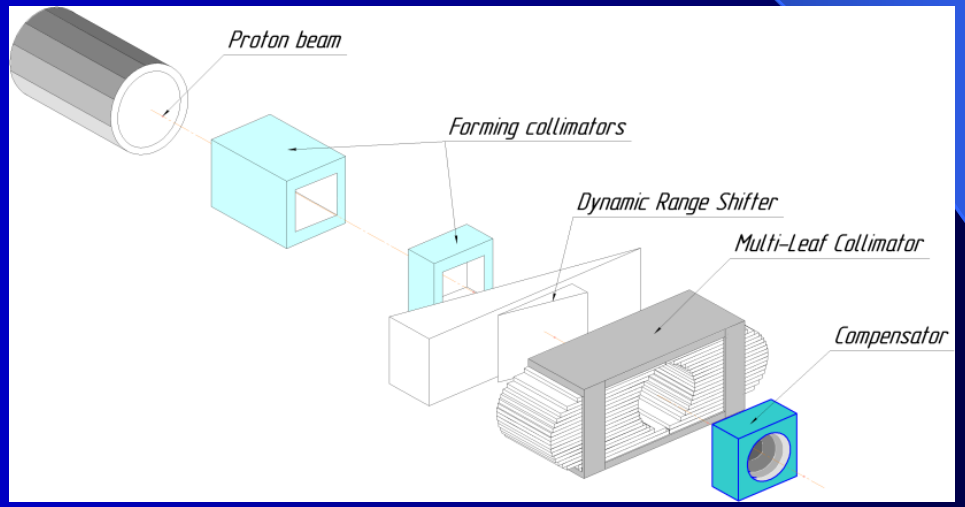
1999, December – inauguration of a Radiological Department of the Dubna hospital;

1999-2019, June – about 1300 patients underwent proton radiotherapy courses. Realization of the technique for 3D conformal proton radiotherapy.

Layer-stacking technique of irradiation is under development

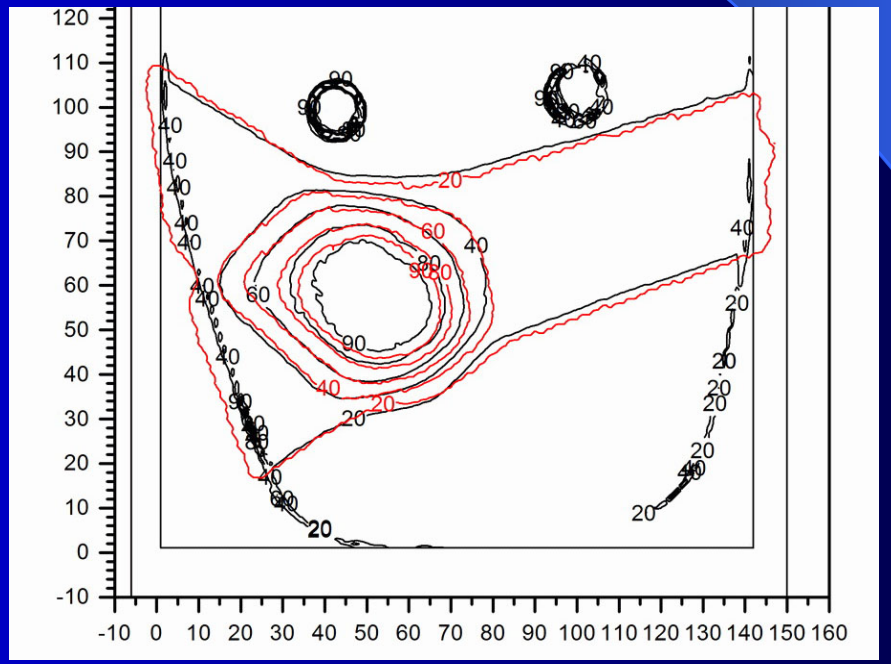
A target volume is virtually divided into several thin layers in the depth direction using a Multi-Leaf Collimator and a Dynamic Range Shifter . These imaginary individual layers are irradiated with the non-modified proton beam, different beam energies (ranges), and conformal fields.





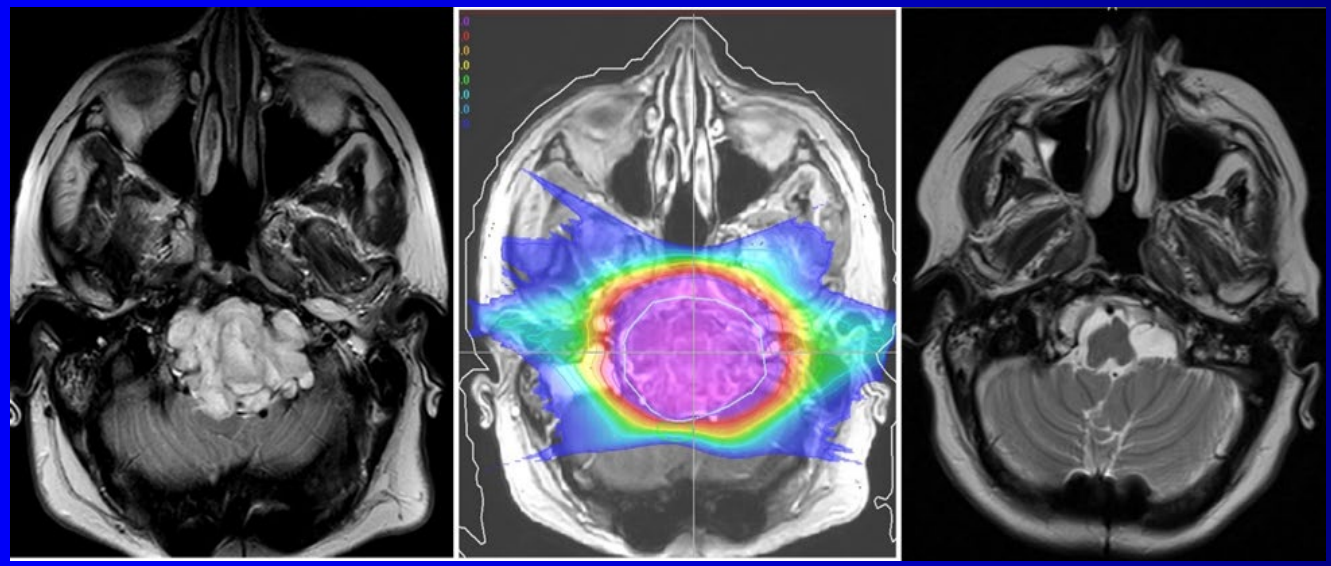
Three-Dimensional Computer Treatment Planning

A 3D treatment planning software have been developed . A set of dosimetric measurements utilizing heterogeneous “Alderson phantom” and radiochromic films has been performed to verify calculation algorithm with good coincidence of calculated and measured dose distributions.



For one of the diseases treated at the MTC, namely intracranial arteriovenous malformation (AVM) a statistical analysis of the treatment results was carried out earlier. Over the past 3 years, we processed the results of proton therapy of chordomas and chondrosarcomas of the skull base for total of 28 patients. The average tumor volume was 42 cm^3 (3.9 cm^3-154 cm^3). The average total dose to the tumour was equal to 73 Gy (63-80 Gy). Dose to critical structures did not exceed tolerant values.

According to the statistical analysis, the following conclusions can be drawn: proton radiosurgery and radiotherapy conducted with the beams of the JINR Phasotron is a highly effective and safe method of treatment of AVM of the brain, including AVM of large size, as well as the chordomas and chondrosarcomas of the skull base, which, due to the close location to the critical structures of the brain, are the most complex of all intracranial targets. The results obtained are close with the data of other centers of proton therapy.



Studies in the Field of Radiation Biology

It was shown that both preliminary and subsequent, and simultaneous with laser radiation irradiation of fibroblasts in mice leads to an increase in the survival of cells exposed to gamma-radiation or protons. According to the results of the research, 3 patents for inventions were obtained, several compact devices for radiation protection of biological objects in the experiment were designed, which have already shown high efficiency in radiation protection of the skin and mucous membranes of patients undergoing radiotherapy in the MTC.

Фиг.3

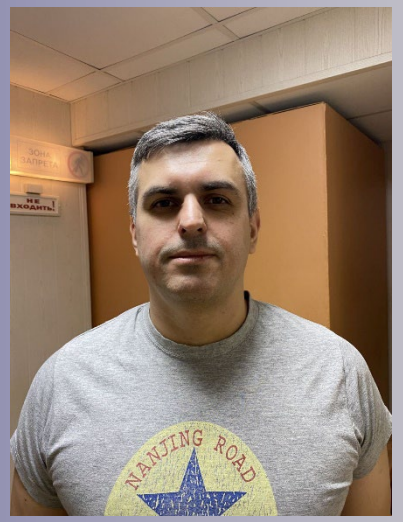
Joint work is being carried out within the framework of the cooperation program with South Africa (iThemba LABS) on the topic "Neurochemical studies of neurotransmitters in brain tissues after exposure to neutrons, protons and gamma quanta".

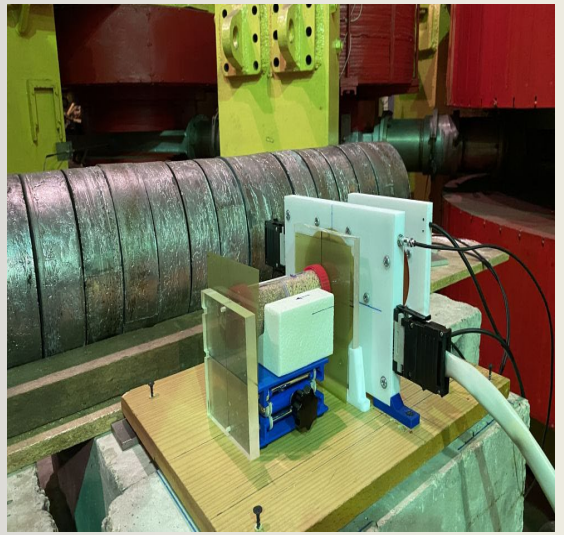
Researches have also been started on the flash-irradiation of normal and tumor cells, as well as mice, with the Phasotron proton beam of 660 MeV with a dose rate of about 70 Gy/s. Radiobiological reactions (clonogenic survival, cell proliferative activity, cytogenetic damage (micronuclear test, γH2AX- foxy) are studied, the formation of reactive oxygen species is investigated.

Project "Further development of methods, technologies, schedule modes and provision of radiotherapy"

MTC

FTE 18 Young colleagues 4

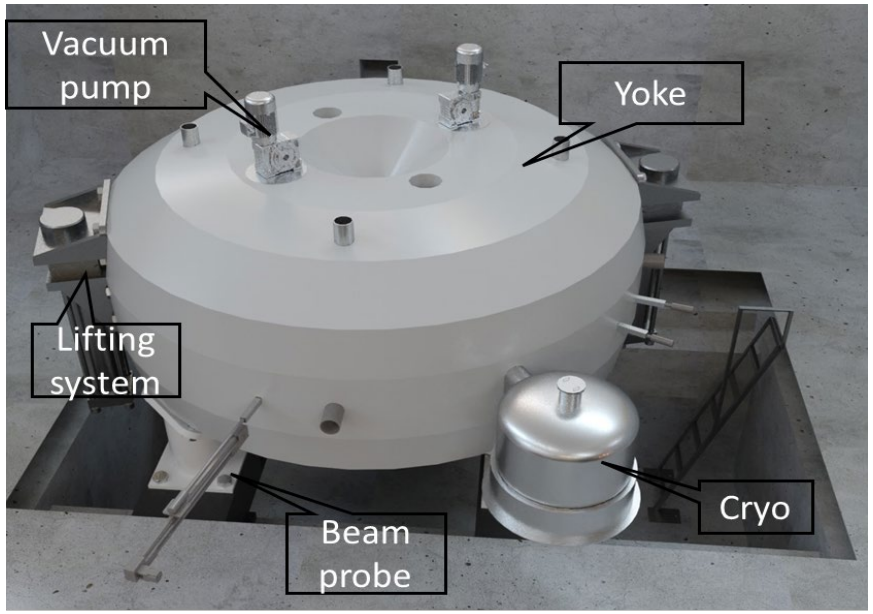




Development of methods and programs for creating cyclotron-type accelerators. Development and upgrade of cyclotrons for medical application

G.A. Karamysheva

- MSC 230 is cyclotron designed for biomedical and preclinical research in proton therapy and radiation biology
- MSC 230 is an isochronous cyclotron with superconducting coils of the main magnet
- The maximum energy of the beam is 230 MeV, the weight of the magnet is about 100 tons
- Designed for delivering high dose rate irradiation for FLASH therapy studies
- An agreement on technical cooperation with NIIEFA (St. Petersburg) on the design of the MSC 230 for the JINR Innovation Center is signed



Dzhelepov Laboratory of Nuclear Problems

Study of the radioprotective properties of the Damage suppressor (Dsup) protein on a model organism D.melanogaster and the human cell culture HEK293

Project leader Kravchenko Elena

Tardigrades have a well-developed nervous system, with the brain, muscle, digestive and other systems, consisting of differentiated tissues.

Found in all biomes from the Arctic to the Antarctic, on mountain peaks, in deep-sea springs and cold mud springs in the west of Greenland.

Tardigrades belong to the group of the most radiation-resistant animals on Earth, able to survive after exposure to both rare and dense ionizing radiation

Organism	LD_{50}	Author
Homo sapiens	$LD_{50/30d}$ =2.5–4.5 Gy	Bolus (2001)
Mouse	$LD_{50/30d}$ = 4.5 Gy	Bolus (2001)
Gold fish	$LD_{50/30d}$ = 8 Gy	Bolus (2001)
Cockroach	$LD_{50/30d}$ = 50 Gy	Bolus (2001)
Drosophila melanogaster (Insecta)	$LD_{50/3}$ = 1238–1339 Gy	Parashar et al. (2008)
Deinococcus radiodurans (Bacteria)	LD_{50} = 10000 Gy	Makarova et al. (2001)
Escherichia coli (Bacteria)	LD_{50} = 600 Gy	Krisko and Radman (2010)
Tardigrades	LD_{50} = 1270–5000 Gy	Hashimoto and Kunieda (2017)

Tardigrades are a model organism for studying the influence of space conditions on living organisms

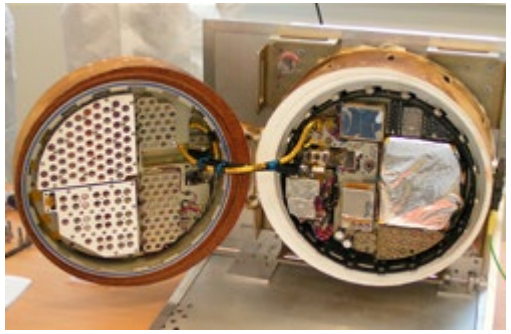
FOTON-M3 mission

TARDIS (Jönsson et al., 2008), RoTaRad (Persson et al., 2011), TARSE (Rebecchi et al., 2011, 2009)

TARDIS (Tardigrades in Space) tardigrades were exposed to space vacuum (10^{-6} Pa), space radiation (100 mGy) and UV radiation for 10 days.

Exposure to vacuum and cosmic radiation did not significantly affect survival. (Jönsson et al., 2016, 2008).

http://teamtardigrades.blogspot.com/



Current Biology

CellPress

Correspondence

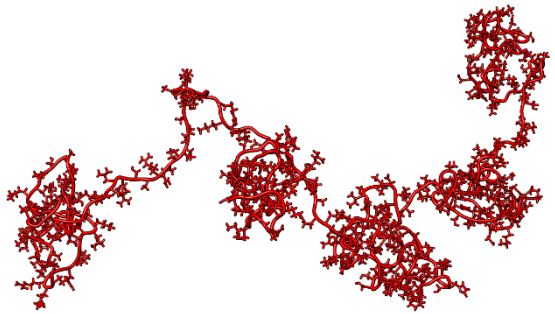
Tardigrades survive exposure to space in low Earth orbit

K. Ingemar Jönsson [1], Elke Rabbow [2], Ralph O. Schill [3], Mats Harms-Ringdahl [4], Petra Rettberg [2]

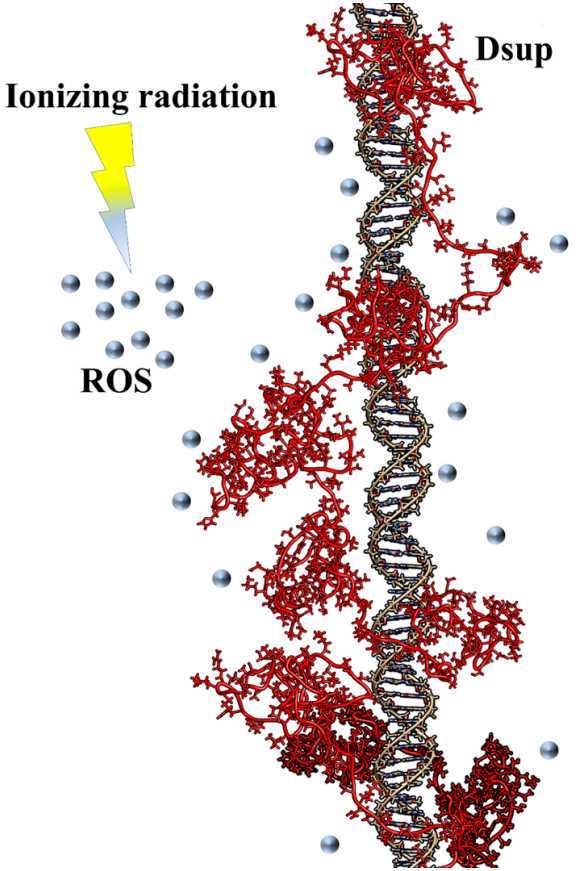
Molecular mechanisms of radioresistance in tardigrades

In 2016, the genome of *Ramazzottius varieornatus*, one of the most radioresistant tardigrade species, was sequenced (Hashimoto et al., 2016).

After comparing *R. varieornatus* proteins with all known proteins from other organisms, a unique Damage suppressor (Dsup) protein was found, which is present only in tardigrades. This protein is responsible for the unique radioresistance.

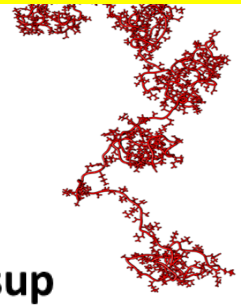


The structure of Dsup protein modeling with I-TASSER



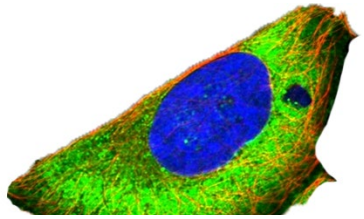
We created model lines of Drosophila and human cell cultures in which Dsup was expressed. After irradiation with gamma rays at a dose of 500 Gy, Drosophila with Dsup survived 40% better. After irradiation with protons at a dose of 4 Gy, human cells with Dsup survived 6 times better. Thus, the Dsup protein is able to work as a radioprotector in model objects.

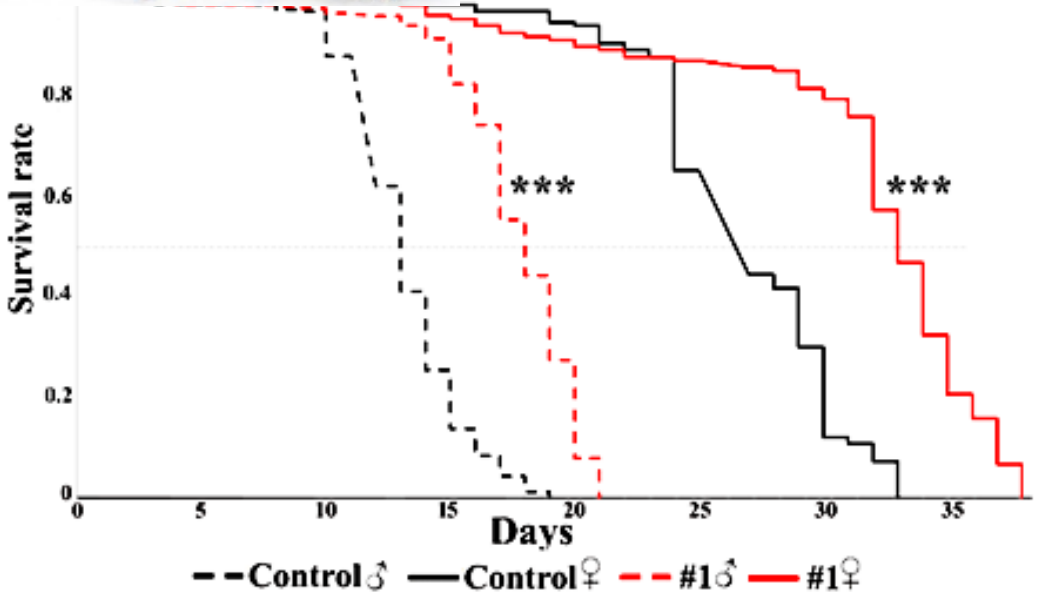
Fruit fly



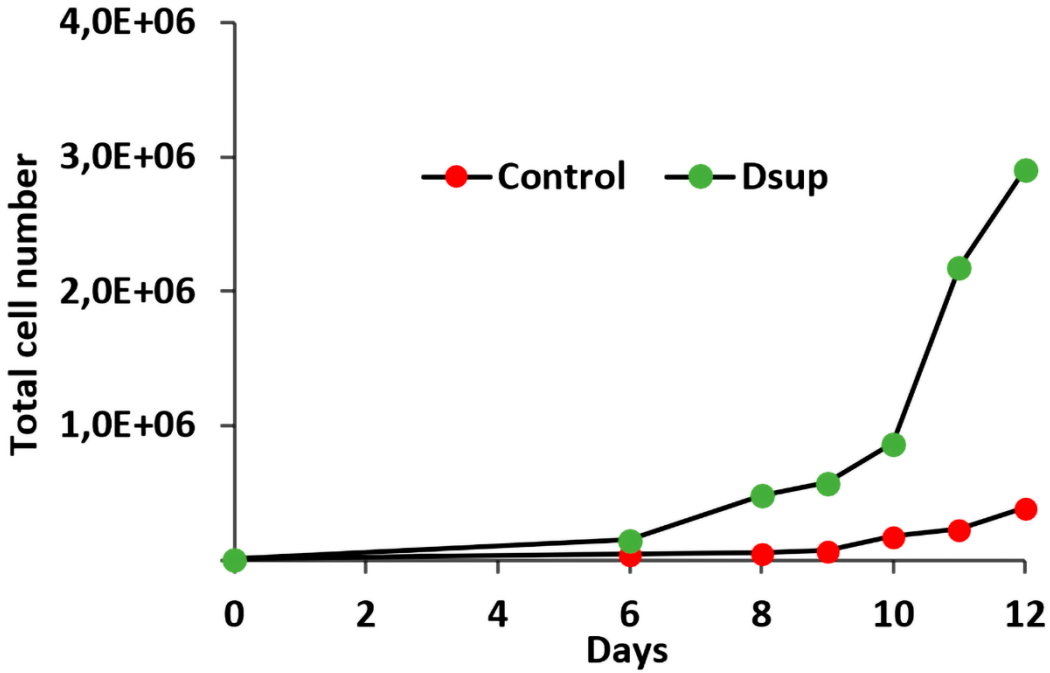
Dsup

Human cell culture

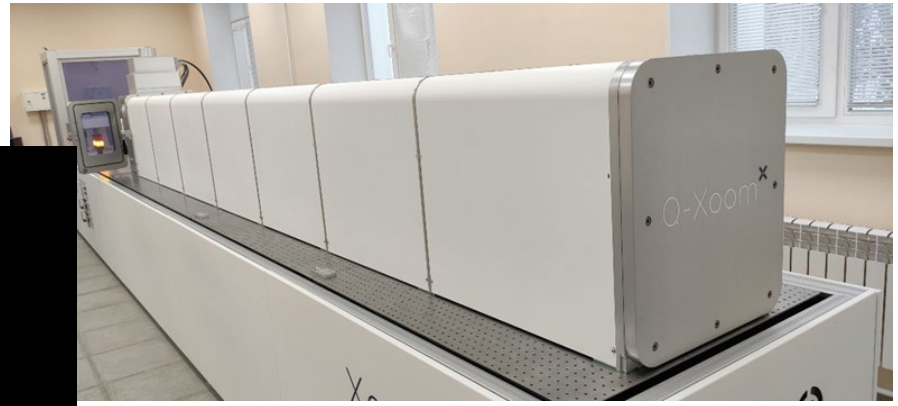


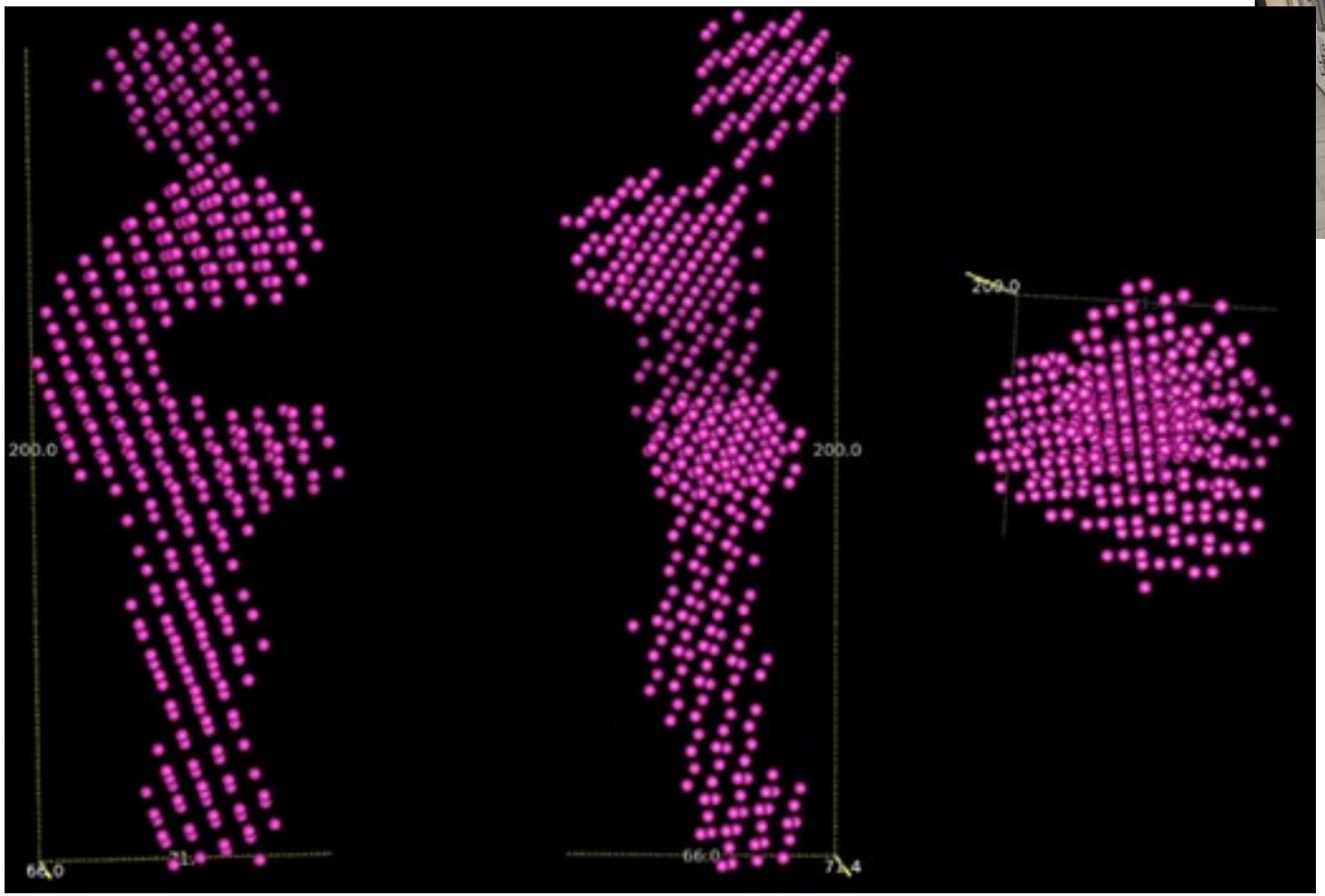


MT-25, FLNR JINR, γ, 500 Gy



Phasotron, DLNP JINR, p^+, 4 Gy





Model of Dsup structure derived from experimental data (DAMMIF package)
Experiments in collaboration with FLNP JINR (SAXS and DLS)

Dsup can be used in

- **Biotechnology:** for increasing of radiation resistance in agricultural and biotech organisms
- **Astrobiology&Spaceflight biology:** development of model organisms for non-human space studies and pharmacological support of cosmonauts and their microbiomes
- **Pharmacy:** stabilizer and cryoprotectant of vaccines and other DNA/RNA-containing pharmaceuticals for effective manufacturing, transportation and conservation
- **Medicine:** antidote agent for radiotherapy, chemotherapy and other harsh medical procedures or as capsule for radiopharmaceuticals
- **Ecology:** creation of biotechnological cultures for bioremediation of toxic solutions as wastes of nuclear industry

The main results of the project

-Dsup protein is an effective radioprotector that increases radioresistance of model organisms

-Dsup protein affects some other biological processes

-Dsup is rod-shaped DNA binding protein

Plans

-development of a system with controlled switching on and off activity of Dsup in living model organism (*D.melanogaster*)

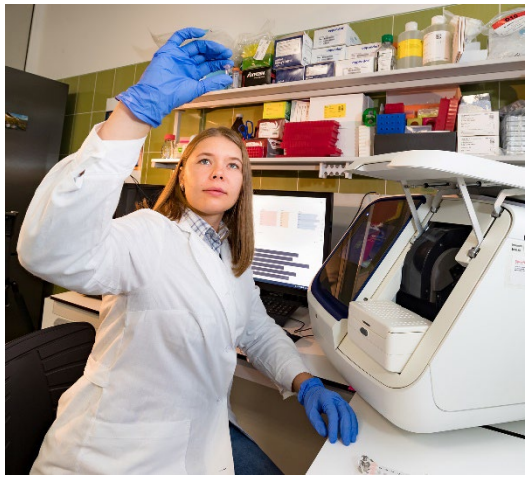
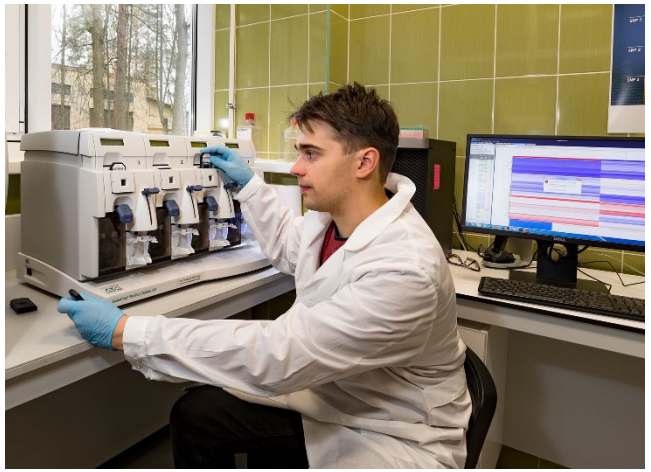
-ATAC sequencing for evaluation the effect of Dsup on DNA compaction in the nucleus

Study of the radioprotective properties of the Damage suppressor (Dsup) protein on a model organism D.melanogaster and the human cell culture HEK293

FTE **10** Young colleagues **6**

Estimated cost, kUSD

2024	2025	2026	2027	2028	2029	2030	Total
40	40	40	40	40	40	40	280

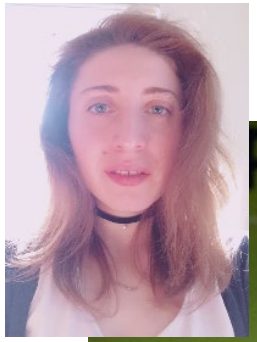
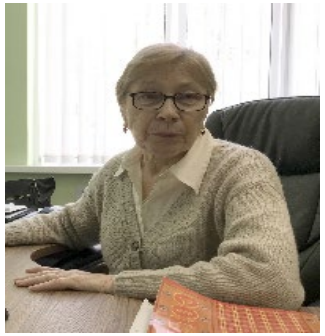

Dzhelepov Laboratory of Nuclear Problems

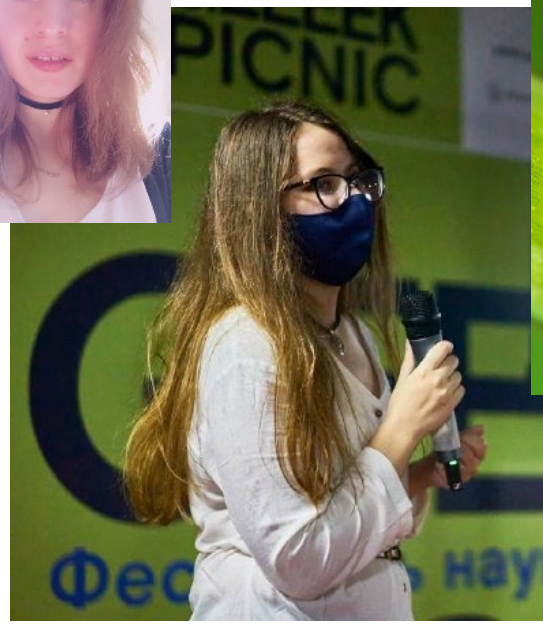
RADIOGENE: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in Drosophila melanogaster

Authors: :

I.D. Alexandrov, M.V. Alexandrova, K.P. Afanasyeva, S.V. Korablinova, L.N. Korovina, N.V. Orlova, A.N. Rusakovich, O.P. Solodilova, N.E. Kharchenko





Problem:

Forecasting (prediction) *de novo* mutations in the progeny of irradiated parents.

Relevance:

The problem remains poorly studied so far, despite the growth of human contact with ionizing radiation on Earth and in space and the growing threat of nuclear catastrophes.

Goal of the project:

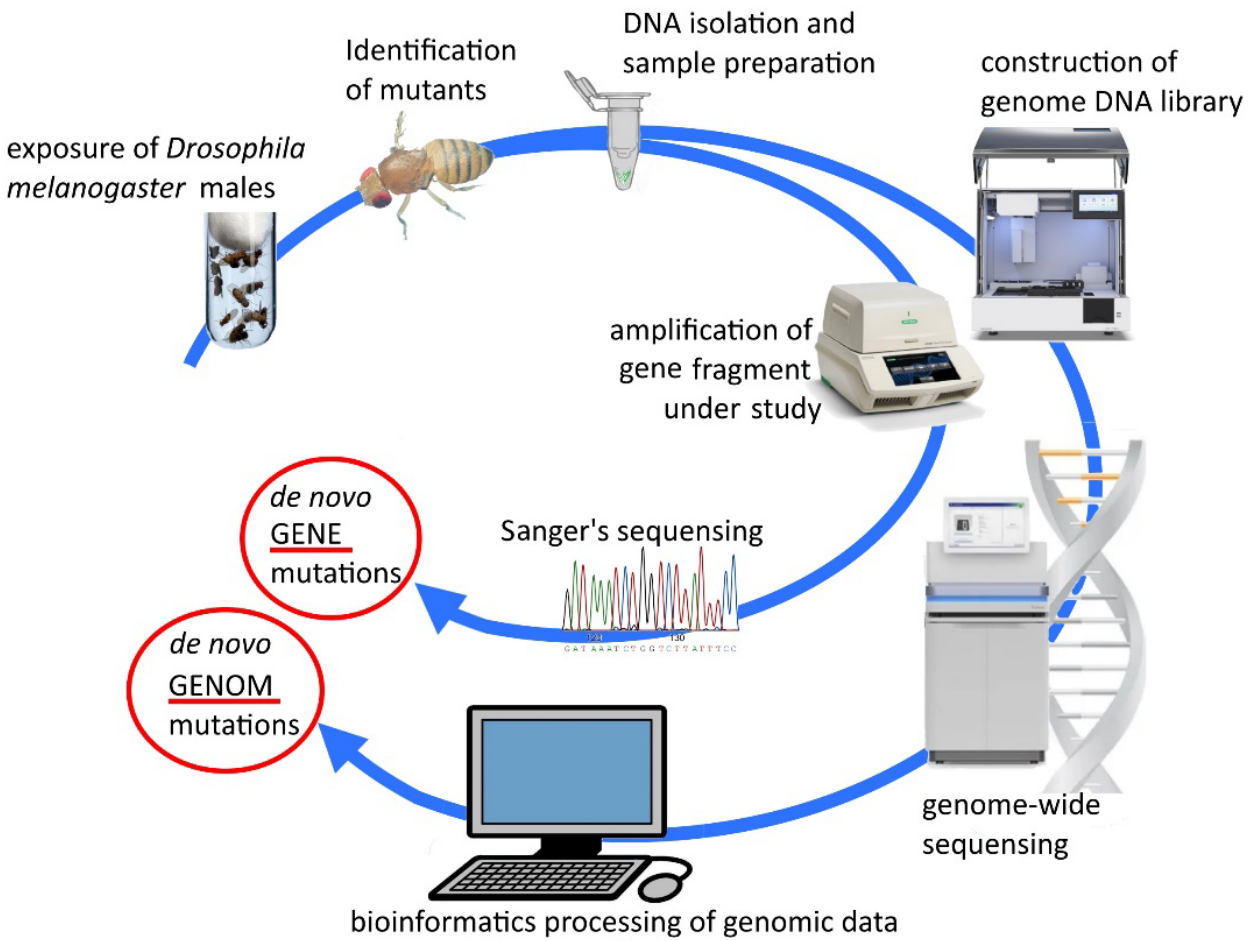
Investigation of the molecular nature and rate of *de novo* gene and genome mutations in the progeny of irradiated *Drosophila melanogaster* males.

Approaches:

1. Sanger's sequencing of inherited radiation-induced mutations of individual genes;
2. Genome-wide sequencing of progeny of irradiated parents (illumina).

Types of radiation used :

γ-rays ^{60}Co (E=1,3 MeV, LET=0,3keV/µm, 5-60 Gy)
monoenergetic reactor neutrons (E=0.85 MeV, LET=78 keV/µm, 2.5-20 Gy).



Stages of implementation of two approaches for sequence analysis of DNA changes at the gene and genome levels.

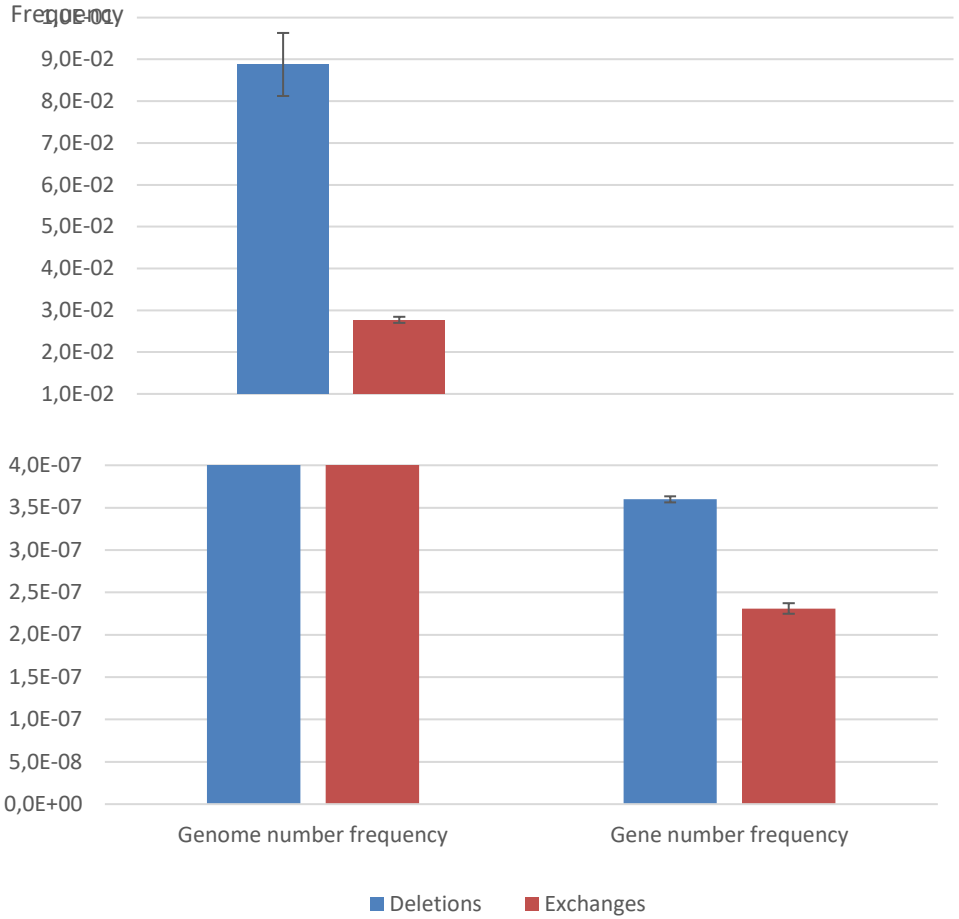
We analyzed irradiation results at the level of individual genes and at the level of the whole genome.

The genomic approach makes it possible to obtain data on all heritable induced changes for several genomes in one experiment in a short time.

Among the detected changes, deletions and chromosomal exchanges predominate.

Their frequency per 1 Gy per genome is almost 4 orders of magnitude higher than per 1 Gy per gene.

These data show that progeny can inherit many more changes at the genomic level than previously thought, when studied at the level of individual genes.

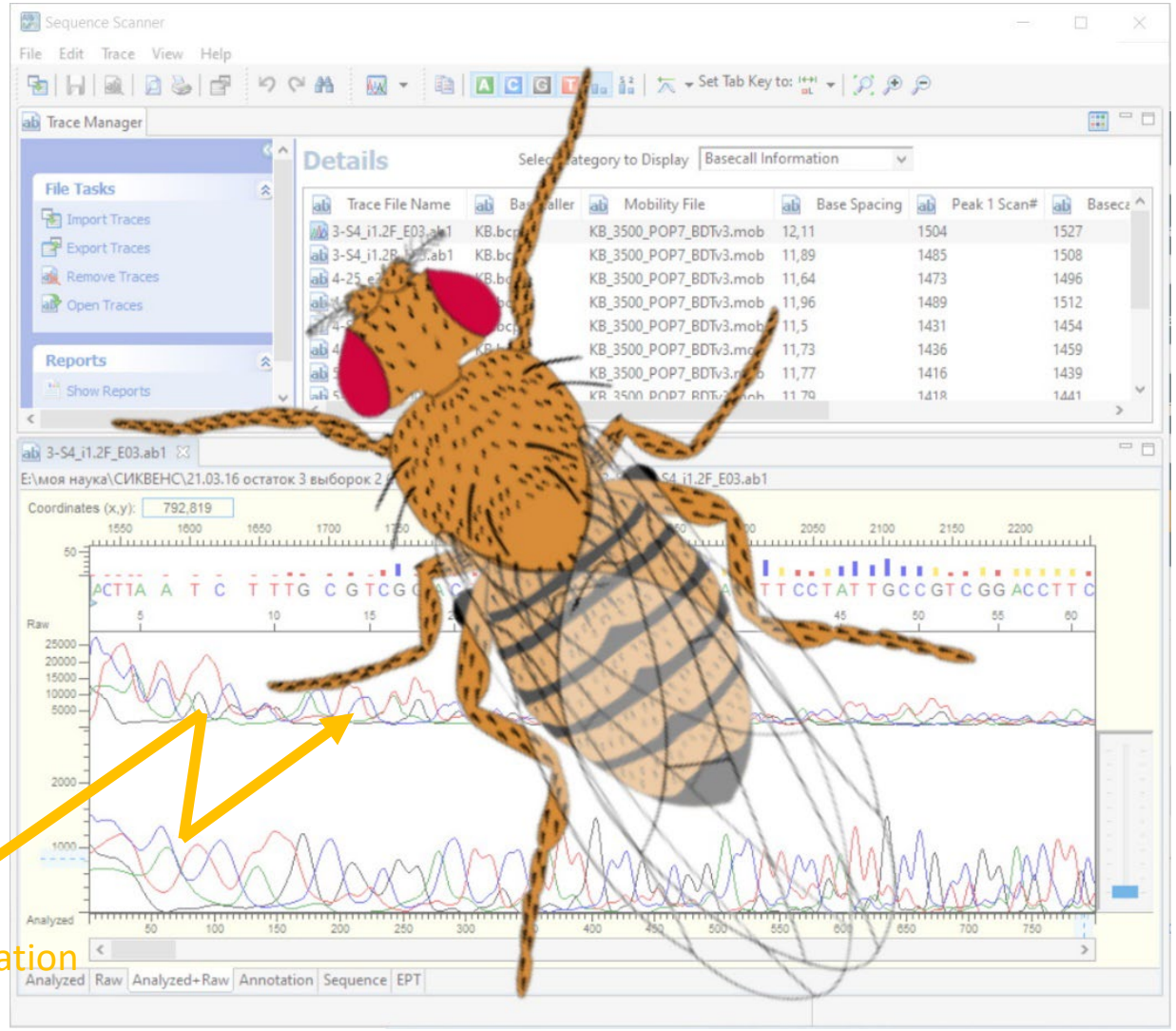


Comparative frequency of two main types of DNA changes (deletions and chromosomal exchanges), recovered by Sanger's sequencing of 5 gene studied and genome-wide sequencing of the progeny genomes.

Outlook:

1. To continue the research on the molecular nature and frequency of inherited γ-ray- and neutron-induced mutations in other genes using Sanger's sequencing.

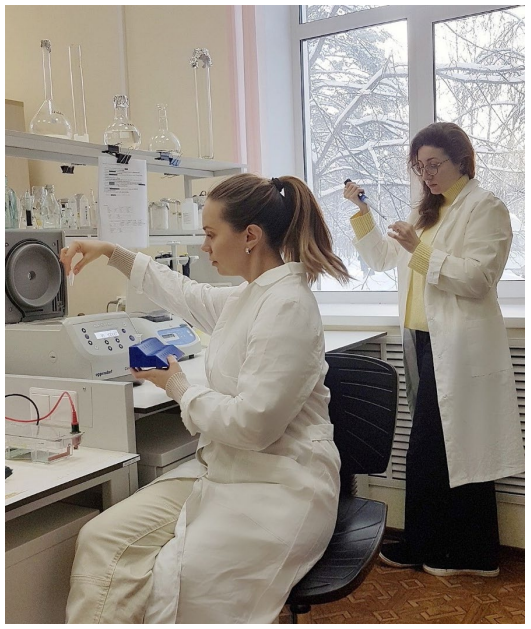
2. Development of research on genomic sequencing of the progeny of Drosophila males in control and after exposure to sparsely and densely ionizing radiation of different types.



sparsely and densely
ionizing radiation

RADIOGENE: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in Drosophila melanogaster

FTE 10 Young colleagues 4



Cost estimate (kUSD)

	2024	2025	2026	2027	2028	2029	2030	**Total**
	40	30	30	40	30	30	30	**230**


Thank you for your attention
A1AA
A1AA

BACKUP

Main fields of the researches:

- Development of the techniques for proton radiotherapy;
- Clinical research;
- Dosimetry of therapeutic hadron beams;
- Radiobiology.