имени Векслера и Балдина
ЛАБОРАТОРИЯ ФИЗИКИ ВЫСОКИХ ЭНЕРГИЙ

Конкурс на соискание Премий ОИЯИ
для молодых ученых и специалистов

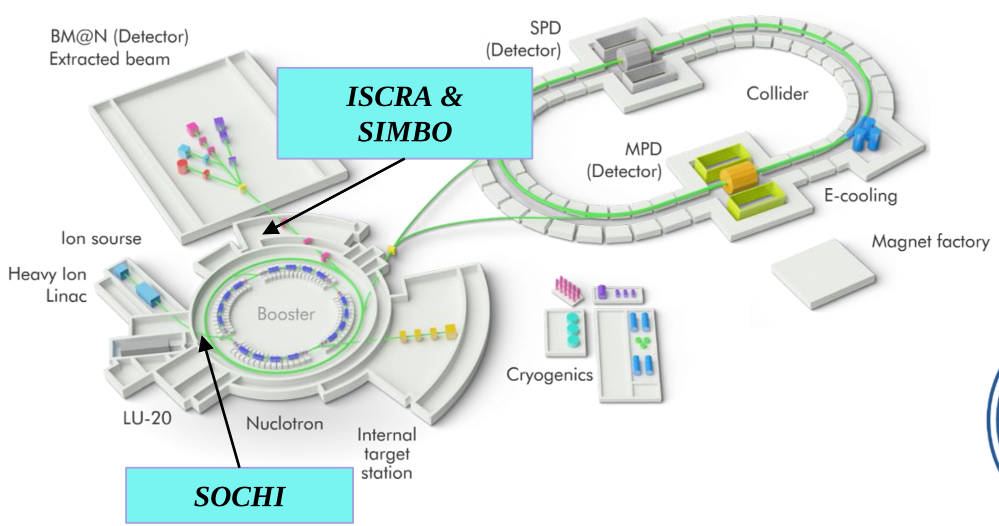
Construction of stations for applied research at the NICA accelerator complex at JINR

Presenter: Alexey Slivin (JINR, Dubna, Moscow Region)

Authors: Alexey Slivin, Alexey Agapov, Anton Baldin, Andrey Butenko, Georgii Filatov, Konstantin Shipulin, Evgeny Syresin, Gennady Timoshenko, Alexey Tuzikov *(JINR, Dubna, Moscow Region)*, **Timur Kulevoy , Yuriy Titarenko** *(Institute for Theoretical and Experimental Physics of National Research Centre "Kurchatov Institute", Moscow, Russia)*, **Dmitry Bobrovskiy, Alexander Chumakov, Sergei Soloviev** *(Specialized Electronic Systems (SPELS) and National Research Nuclear University (NRNU) "MEPHI", Moscow, Russia*), **Alexander Kubankin** *(LLC "Vacuum systems and technologies", Belgorod, Russia)*, **Pavel Chernykh, Sergey Osipov, Evgeny Serenkov** *(Ostec Enterprise Ltd, Moscow, Russia)*, **Vladimir Luzanov, Igor Glebov** *(LLC "GIRO-PROM", Dubna, Russia)*

15 December 2021

An applied research based on the NICA accelerator complex



On the basis of the NICA accelerator complex applied stations: ***ISCRA*** (energy range of 150 - 500 MeV/n), ***SOCHI*** (ion energy up to 3.2 MeV/n), and ***SIMBO*** (energy range 500-1000 MeV/n) are under construction for single event effects testing of as capsulated, so decapsulated microchips, and for radiobiological research and modelling of influence of heavy charged particles on cognitive functions of animal's brain respectively. This report presents the applied stations description.

- ***ISCRA*** — ***I***rradiation ***S***etup for ***C***omponents of ***R***adioelectronic ***A***pparature. Heavy ions with the energy of 150..500 MeV/n
- ***SOCHI*** — ***S***tation of ***CH***ip ***I***rradiation. Heavy ions with the energy of 3.2 MeV/n
- ***SIMBO*** — ***S***etup for ***I***nvestigation of ***M***edical ***B***iological ***O***bjects. Heavy ions with the energy of 500..1000 MeV/n

ARIADNA
beamlines

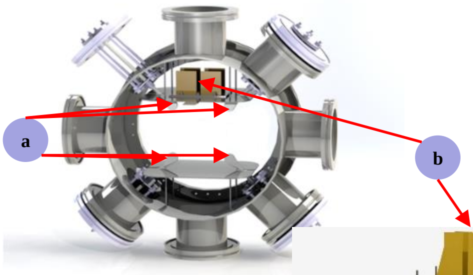
Applied **R**esearch **I**nfrastructure for **A**dvanced **D**evelopments at **N**ICA f**A**cility

Station of CHip Irradiation (SOCHI)

*General view of the **SOCHI** station*

SOCHI – an applied research station for decapsulated microchips for Single Event Effects (SEE) testing (ion energy up to 3,2 MeV/n)

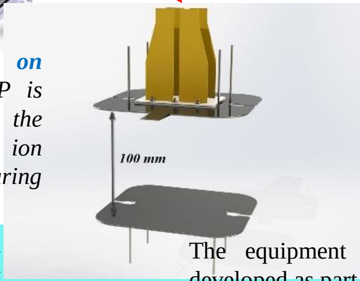
a) ***The system for online diagnostics and control of peripheral ion flux density and fluence*** *is comprised of four scintillation-fiber detectors based on multichannel photomultipliers*



b) ***The ionization detector based on microchannel plates*** *(**MCP**). The MCP is used for nondestructive control of the intensity and spatial distribution of the ion beam in the horizontal plane during irradiation at the SOCHI station.*

Technical requirements for the ion beams at the SOCHI station

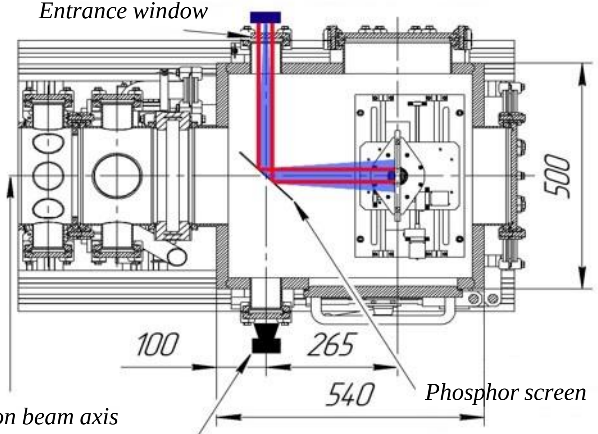
Ion types	$^{12}C^{4+}$, $^{40}Ar^{8+}$, $^{131}Xe^{22+}$, $^{84}Kr^{14+}$, $^{169}Tm^{21+}$, $^{197}Au^{31+}$, $^{209}Bi^{34+}$
Ion energy at the exit from the HILac, MeV/n	3,2
Ion flux density, particles/(cm^2·s)	$10^2..3\cdot10^5$
Maximum fluence per run, ion/(cm^2)	$2\cdot10^7$
Irradiation time per run, min	30-40
Maximum irradiation area, mm	Ø29
Uniformity in the beam center at the 20x20 mm area, %	10



The equipment for the SOCHI station is being developed as part of the ***JINR-ITEP*** collaboration with ***SPELS/MEPhI-VST-GIRO-PROM*** participation

Station of CHip Irradiation (SOCHI)

The ***fast total-absorption phosphor detector*** with optical readout is used to measure beam profiles.



Location of the fast phosphor detector and it's signal acquisition system in the vacuum chamber No. 3

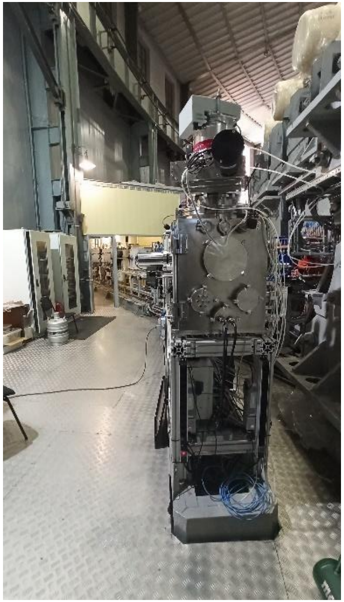
A ***Faraday*** *cup*

The ***fast total-absorption scintillation detector*** with optical readout is used to control the ion flux density and flux stability in time.

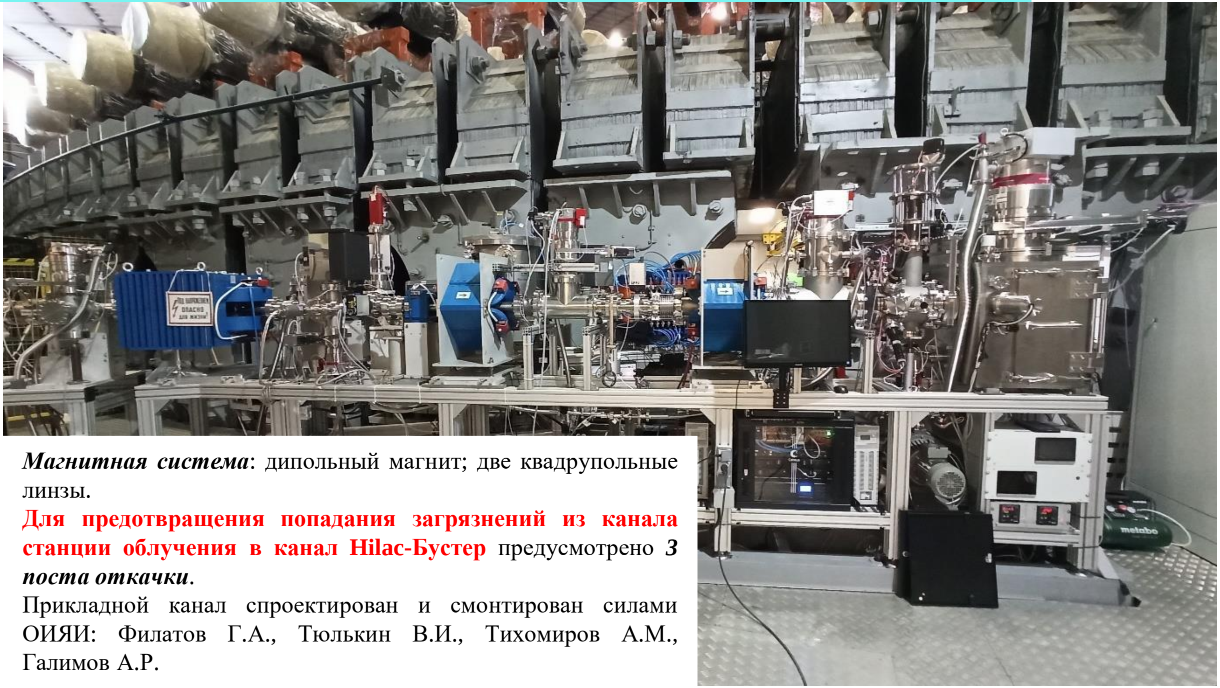
Конкурс на соискание Премий ОИЯИ для молодых ученых и специалистов

The equipment for the SOCHI station is being developed as part of the ***JINR-ITEP*** collaboration with ***SPELS/MEPhI-VST-GIRO-PROM*** participation

Station of CHip Irradiation (SOCHI)



Станция СОЧИ в Корпусе № 1 ЛФВЭ



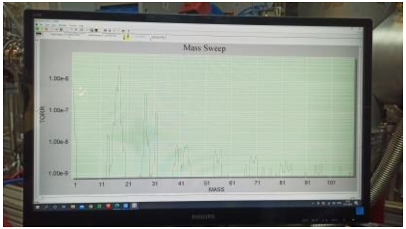
Магнитная система: дипольный магнит; две квадрупольные линзы.

Для предотвращения попадания загрязнений из канала станции облучения в канал Hilac-Бустер предусмотрено ***3 поста откачки***.

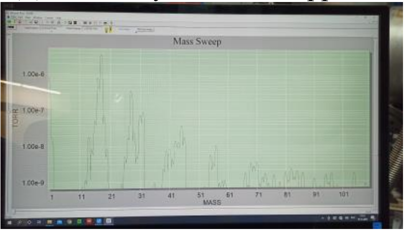
Прикладной канал спроектирован и смонтирован силами ОИЯИ: Филатов Г.А., Тюлькин В.И., Тихомиров А.М., Галимов А.Р.

The equipment for the SOCHI station is being developed as part of the ***JINR-ITEP*** collaboration with ***SPELS/MEPhI-VST-GIRO-PROM*** participation

Station of CHip Irradiation (SOCHI)



Состав остаточного газа при «холодных» испытаниях. Показания газоанализатора XT100. Давление лучше 10^{-6}торр



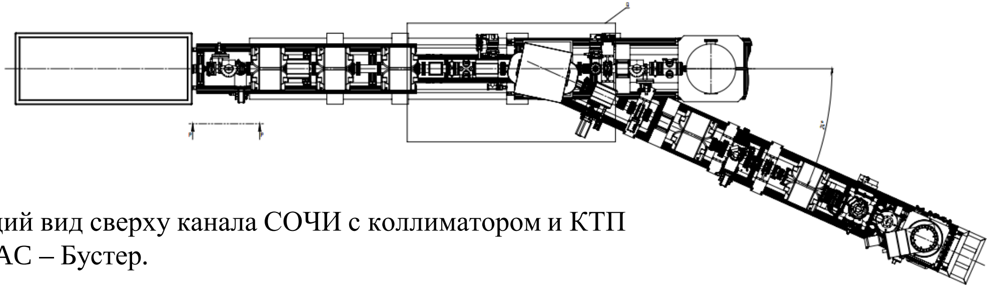
Состав остаточного газа при «горячих» испытаниях. Показания газоанализатора XT100. Давление $3{,}5 \cdot 10^{-6}$торр

Вакуумные испытания проводились в три этапа:

- «Холодные» испытания основной вакуумной камеры и двух диагностических камер
- «Горячие» испытания основной вакуумной камеры и двух диагностических камер
- Вакуумные испытания канала после пристыковки к диагностическим камерам

Вакуумные испытания завершились 14 декабря 2021.

Проектный вакуум в станции 10^{-5}торр, проектное время выхода – не более 10 мин.

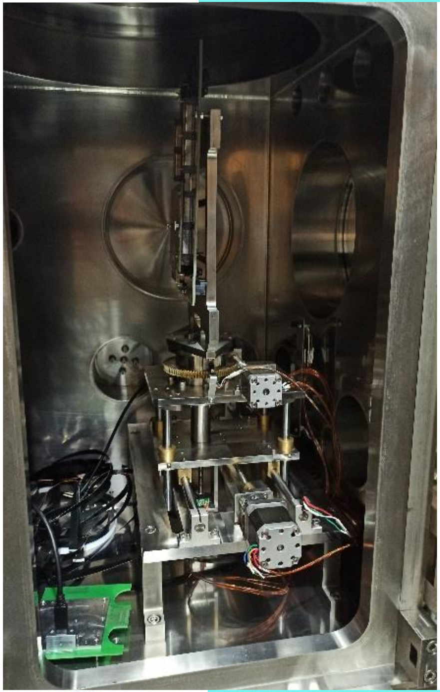


Общий вид сверху канала СОЧИ с коллиматором и КТП HILAC – Бустер.

Два режима работы станции:

– Специализированный сеанс по испытанию изделий полупроводниковой микро- и наноэлектроники
– В ходе сеанса работы коллайдера, с периодичностью примерно в 1 час, примерно в течении 40 минут циркуляции ионных пучков в коллайдере инжекционный комплекс будет использован для инжекции в прикладной канал на станцию

Station of CHip Irradiation (SOCHI)

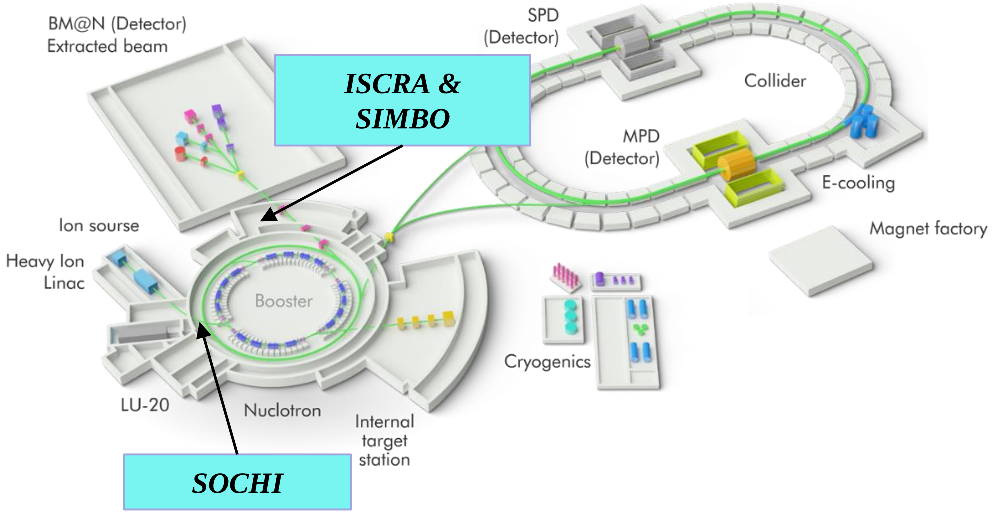


Внутри главной вакуумной камеры (*слева*) находятся:
основная коммутационная плата для подключения адаптера с объектом облучения – 1 шт., эквивалент платы-адаптера с объектом облучения – 1 шт., нагревательный модуль – 1 шт., промежуточная коммутационная плата – 2 шт., кабели для соединения промежуточной коммутационной платы с основной коммутационной платой – 1 комп., кабель USB – 1 шт., кабель Ethernet 1 шт., кабель BNC – 2 шт., высоковольтный кабель – 1 шт., установленные на штатные места газоанализатор, система позиционирования объектов испытаний, фланцы с разъемами, люминофорный детектор полного поглощения.

Пульт управления станцией СОЧИ (*справа*) в Корпусе № 1 ЛФВЭ:

- Моноблоки (2 шт.), обеспечивающие управление контрольно-измерительным оборудованием во время проведения эксперимента
- Моноблок (1 шт.) управления вакуумной системой
- Моноблок (1 шт.) управления системой позиционирования и системы задания температуры
- ПК (1 шт.) для управления системами диагностики пучка ионов

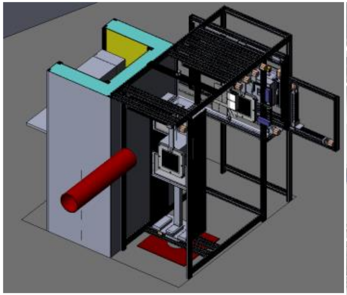
An applied research based on the NICA accelerator complex



- *ISCRA* — *I*rradiation *S*etup for *C*omponents of *R*adioelectronic *A*pparature. Heavy ions with the energy of 150..500 MeV/n
- *SOCHI* — *S*tation of *CH*ip *I*rradiation. Heavy ions with the energy of 3.2 MeV/n
- *SIMBO* — *S*etup for *I*nvestigation of *M*edical *B*iological *O*bjects. Heavy ions with the energy of 500..1000 MeV/n

Irradiation Setup for Components of Radioelectronic Apparature (ISCRA)

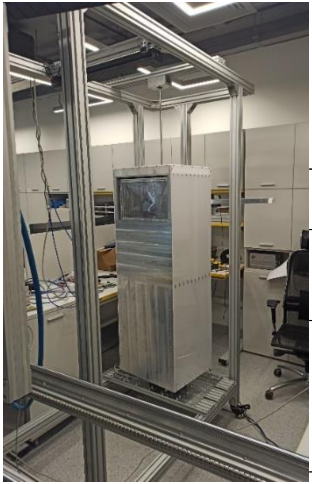
General 3D view of the ISCRA station. Front view



The **red tube** – ion beam (conventional symbol).

The system for positioning and movement of the test samples. Back view

Energy degrader



Technical requirements for the ion beams at the ISCRA station

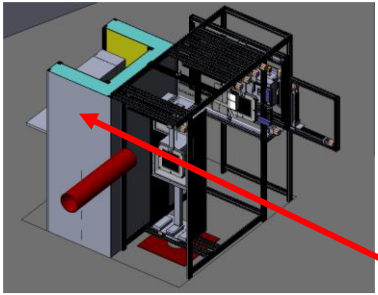
Type of ions, energy MeV/n	$^{197}Au^{79}$	150-350
	$^{131}Xe^{54+}$	150-367
	$^{12}C^{6+}$	150-392
	$^{40}Ar^{18+}$	150-449
	$^{56}Fe^{26+}$	150-426
	$^{84}Kr^{36+}$	150-507
Ion flux density, particles/(cm^2·s)	$10^2..3\cdot10^5$	
Maximum irradiation area in the scanning mode/ nonscanning mode, mm	200x200/Ø29	
Flux uniformity for the maximum irradiation area in the scanning mode/nonscanning mode, %	15/10	
Irradiation time per run, min	30-40	

ISCRA – an applied research station for microchips with a package for Single Event Effects (SEE) testing (energy range of 150-500 MeV/n)

The equipment for the ISCRA station is being developed as part of the ***JINR-ITEP*** collaboration with ***SPELS/MEPhI-GIRO-PROM*** participation

Irradiation Setup for Components of Radioelectronic Apparatus (ISCRA)

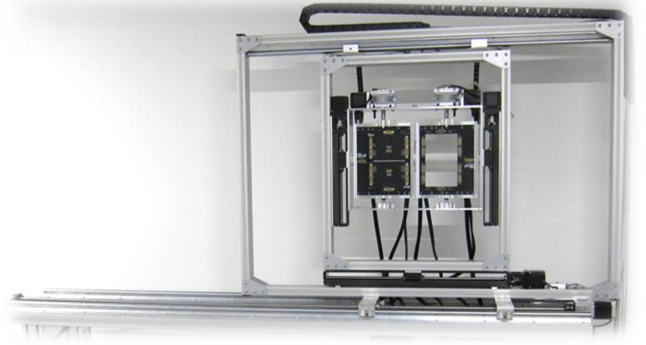
General 3D view of the ISCRA station. Front view



The **red tube** – ion beam (conventional symbol).

ISCRA – an applied research station for microchips with a package for Single Event Effects (SEE) testing (energy range of 150-500 MeV/n)

Protected rack for control and measuring equipment, controllers of the station equipment control systems



The system for positioning and movement

- Two independent rotary frames (from 0 to 90 degrees)
- Four adapter boards with the possibility of simultaneous irradiation in the beam scanning mode
- Automated installation of the object on the beam axis within ± 100 mm vertically, ± 200 mm horizontally
- The positioning of the object on the beam axis is controlled by a video camera with laser illumination of the beam

The equipment for the ISCRA station is being developed as part of the ***JINR-ITEP*** collaboration with ***SPELS/MEPhI-GIRO-PROM*** participation

Irradiation Setup for Components of Radioelectronic Apparatus (ISCRA)

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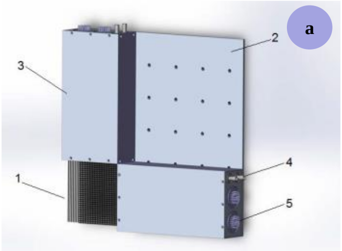
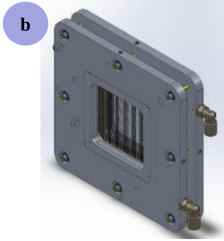


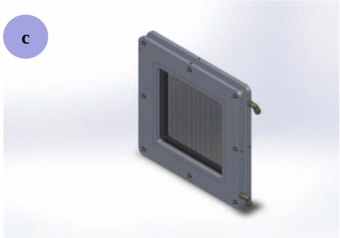
*a) **A 80×80 mm scintillation-fiber detector*** is used ***to measure the ion flux density, beam profile*** before the experiment during beam adjustment

1 - Fibers
2 - Detector mounting and fixation element to the positioning system
3 - Multichannel photomultiplier tube (PMT)
4 - High voltage power connector of PMT
5 - Multichannel signal connector

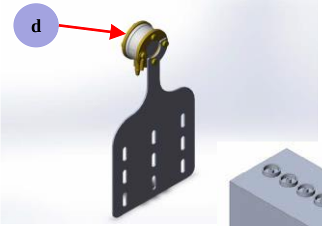
*b) **Ionization chamber № 1 (128×128 mm)*** is used ***to control primary beam parameters in front of the degrader*** before the experiment during beam adjustment



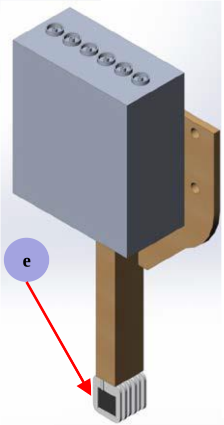
*c) **Ionization chamber № 2 (256×256 mm)*** is used ***to measure the ion flux density of the secondary beam in the target area*** before the experiment during beam adjustment



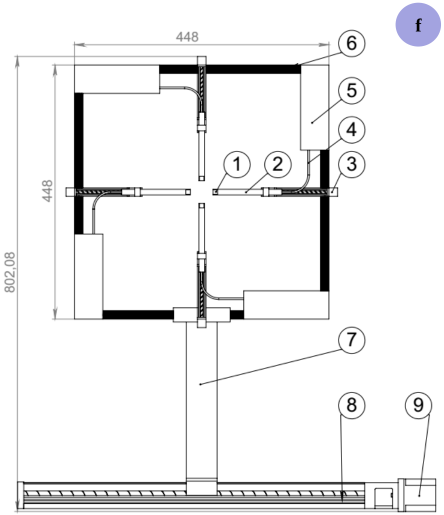
*d) **Miniature gas-filled ionization chamber 3*** is used to measure the LET in the target area before experiment. The working field area is 10x10 mm, the ion energy range is 3-30 MeV/n, the LET measurement range is 5-80 MeV·cm^2/mg.



*e) **A silicon detector (the set of 6 Si-planes)*** — a duplicate detector ***to control and measure the LET of ions in the target area*** before experiment.



*f) **A particle flux density meter based on four scintillators (or four silicon detectors) (No. 1 on the scheme)*** is ***used to control the ion flux density in the peripheral area of the ion beam in real-time.***



NICA

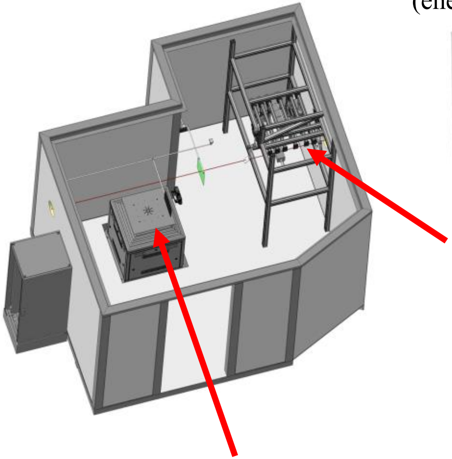
Конкурс на соискание Премий ОИЯИ для молодых ученых и специалистов

The equipment for the ISCRA station is being developed as part of the ***JINR-ITEP*** collaboration with ***SPELS/MEPhI-GIRO-PROM*** participation

Setup for Investigation of Medical Biological Objects (SIMBO)

General 3D view of the ***SIMBO*** *station*

SIMBO ─ an applied research station for space radiobiological research and modelling of influence of heavy charged particles on cognitive functions of the brain of small laboratory animals and primates (energy range 500-1000 MeV/n).



Positioning element for laboratory animals

The beam diagnostics system for the SIMBO station. Side view

Technical requirements for the ion beams at the SIMBO station

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/(cm^2·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

The equipment for the SIMBO station is being developed as part of the ***JINR-VST*** collaboration

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Setup for Investigation of Medical Biological Objects (SIMBO)

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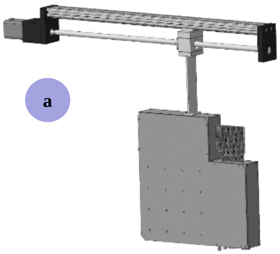
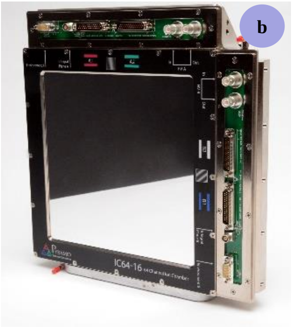
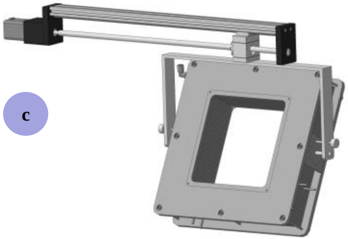


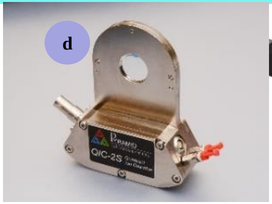
***a)** Diagnostic chamber No. 1 based on scintillation-fiber detectors (is used to measure **ion flux density, beam profiles in nonscanning mode before the experiment during beam adjustment**).*



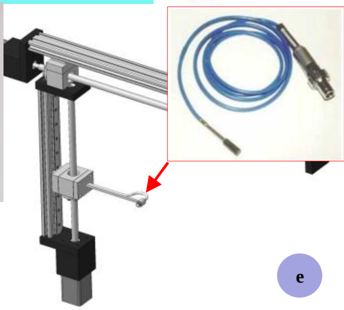
b)** Diagnostic chamber 2 based on the IC64-16 (Pyramid Technical Consultants, Inc)strip ionization chamber is a duplicating chamber for ioniza-tion chamber 1 and **solves similar problems



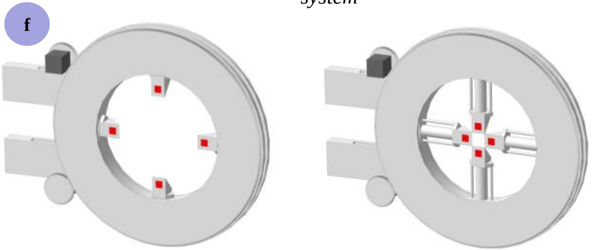
***c)** Ionization dosimetric chamber No. 3 ionization chamber is used to determine **the absorbed dose**.*



d)** Ionization chamber No. 4 based on a model QIC-2S (Pyramid Technical Consultants, Inc) four-channel ionization chamber is used as a **local dose detector



***e)** A diamond semiconductor detector (detector of **the local dose and average ion energy**) installed on the positioning system*

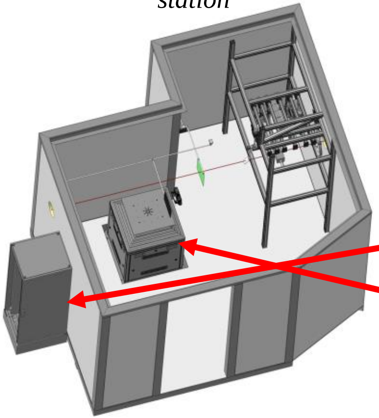


***f)** The system for **online diagnostics and control** of the peripheral ion flux density based on four scintillation detectors.*

Setup for Investigation of Medical Biological Objects (SIMBO)

SIMBO — an applied research station for space radiobiological research and modelling of influence of heavy charged particles on cognitive functions of the brain of small laboratory animals and primates (energy range 500-1000 MeV/n).

General 3D view of the ***SIMBO*** *station*



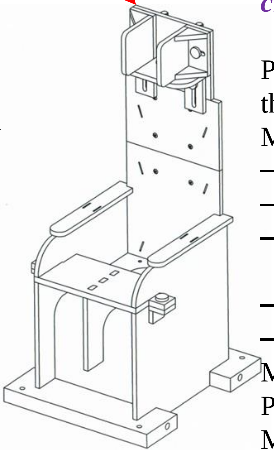
Positioning device for laboratory animals

Positioning device for irradiated objects

Designed for precision linear movement along the longitudinal axis ±100 mm, transverse axis ±100 mm, vertical axis +600 mm, angular movement 10 degrees/sec.

Main structural parts:

— base module;
— basic module;
— elevating module;
— rotation module;
— control unit.



The primate's fixation chair

Placed on the worktable of the positioning device.

Main structural parts:

— base;
— seatback;
— the lower and upper limbs retainers;
— body retainer;
— headrest.

Material of chair - Plexiglass.

Maximum height of the chair with seatback and headrest is 600 mm.

The equipment for Positioning device is being developed as part of the ***JINR-OSTEC GROUP*** collaboration

имени Векслера и Балдина
ЛАБОРАТОРИЯ ФИЗИКИ ВЫСОКИХ ЭНЕРГИЙ

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