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INTERNATIONAL PROJECT ON MBIR REACTOR AS AN INSTRUMENT FOR JUSTIFICATION OF INNOVATIVE NUCLEAR POWER TECHNOLOGIES

Presented by: Alexander Zagornov
Project Director
ROSATOM

MBIR reactor

MBIR is a multipurpose fast neutron research reactor that is going to be the world leader among high-flux research facilities.

Unique reactor characteristics will be best suited for the materials testing, fuel research, structural materials and coolants studies.

MBIR is meant to become the world leader among the high-flux research reactors and provide the nuclear industry with the modern and technologically superb research infrastructure for the upcoming 50 years.

CONSORTIUM IRC MBIR

International Research Center based on MBIR reactor (IRC MBIR) will become a global international science platform for nuclear physics research to justify the development of the two-component nuclear energy.

GENERAL INFO

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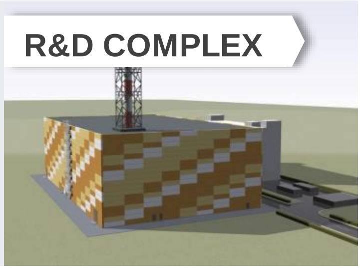

Yuri Olenin
Deputy Director General for Innovation Management ROSATOM

PROJECT MANAGEMENT

Yuri Olenin has been appointed to lead the implementation of the IRC MBIR

PROJECT STRUCTURE

- Poly-Functional Radiochemical Complex (R&D Complex) was incorporated into MBIR project and now available to IRC MBIR Consortium members.
- IRC MBIR consortium members can conduct advanced research in the field of spent nuclear fuel reprocessing, radioactive waste management and closed nuclear fuel cycle straight away.
- IRC MBIR consortium members have access to the BOR-60 reactor to start their research program before the MBIR commissioning.

PROJECT SCHEDULE

- In accordance with the Russian Federal Budget Funding Program and the addition of the R&D Complex to the Consortium the schedule for project implementation was set to 2028.

PURPOSE AND OBJECTIVES OF THE MBIR REACTOR PROJECT

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IRC MBIR Consortium members will have a unique opportunity to test the reprocessing equipment and processes along side the fast reactor, which will allow to perform MA burning, multiple cycles of fuel reprocessing, etc.

Advanced low-absorbing & corrosion-resistant materials	Refractory materials
High-dose irradiation (160÷200 dpa) of new advanced materials	

MOX Fuel burnup 17-20%	Metal Fuel
Mixed nitride uranium - plutonium fuel burnup 8-12%	
MOX/Nitride/Metal with m.a.	Thorium based fuel

- Behavior of FEs under transient conditions, including abnormal ones
- Reactor equipment under transient conditions
- Systems of passive protection of the reactor

- Fuels studies for different compositions, types and burn up rates
- Structural materials studies for Generation IV technologies and life-time extension
- CNCF design, RAW and SNF handling, technologies for multicycle fuel manufacturing
- R&D activities in independent loop channels – modelling of the FE behavior in the core with different coolants
- Testing of new equipment and engineering design configurations
- Safety studies
- Isotopes production (Lu-177, Cf-252, Co-60, Gd-109;153, Sr-85;89, I-125, Xe-127) and other activities – NAA, silicon doping, NCT

MULTILATERAL PROGRAM OF INTERNATIONAL RESEARCH CENTER MBIR

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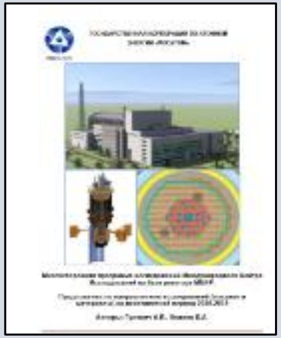
The draft of the Research Program prepared by Russian scientists is uploaded at http://mbir-rosatom.ru/

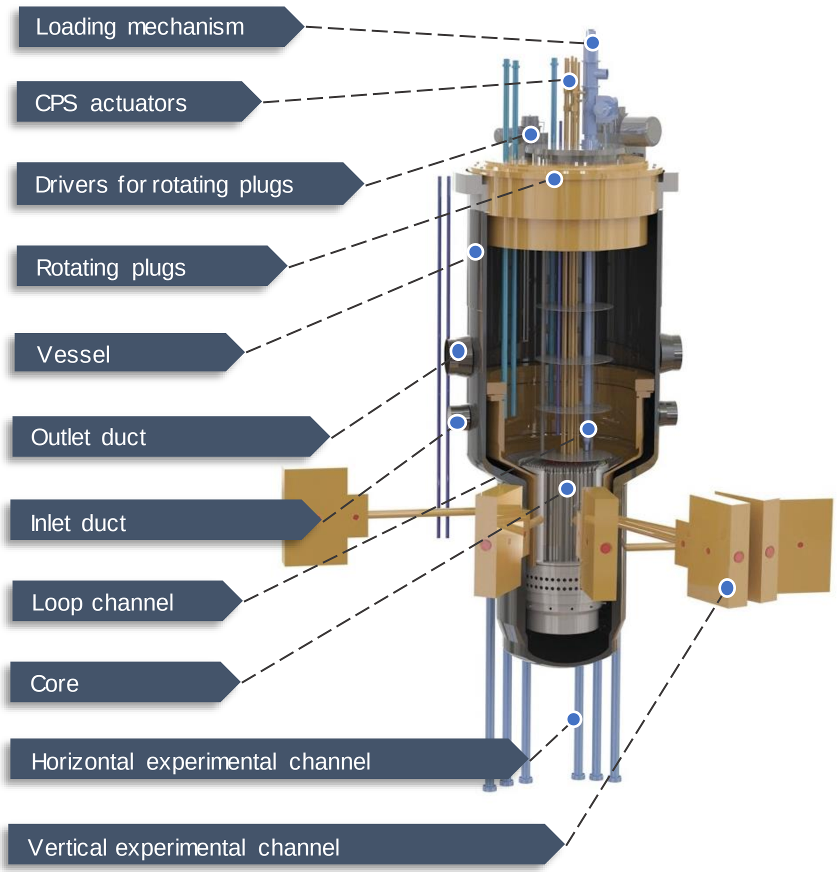


Th e im

If Consortium member is interested in one of the proposed research activities we can together develop a more detailed joined program for more members to join and to promote it within the international organizations for additional funding

- Research into advanced fuel materials performance
- Research into new and modified liquid metal coolants
- Testing of advanced fuel element materials in transient, power cycling and emergency conditions
- Testing of advanced structural materials
- Testing of absorbing, moderating and composite materials for innovative nuclear systems
- Life tests of new equipment types for innovative nuclear systems
- Conducting of reactor physics, materials, thermal hydraulics and other research for computer code verification
- Applied experimental work, using reactor radiation

MBIR REACTOR DESIGN FEATURES



PARAMETER	VALUE
Nominal thermal power, MW	150
Nominal electric power, MW	55
Max / average neutron flux density in the core, $sm^{-2}s^{-1}$	$5{,}3 \times 10^{15}$ / $3{,}1 \times 10^{15}$
Fuel	MOX
Reactor fuel campaigns, not less than, days	100
Safety systems	Active/Hybrid
Number of safety systems	2
Reactor configuration	Loop-type
Number of loops for heat transfer	2
Number of heat removal circuits	3
Coolant Flow	Bottom – up
Coolant: I and II circuits / III circuit	Sodium / Water-steam
Pressure in the I circuit, MPa	до 0,6
Coolant temperature of the I circuit, °C	330-512
Capacity utilization coefficient	0,65
Design lifetime, years	50
Commissioning, year	2028
Unique design features	Combination of the internal and external experimental facilities

CARTOGRAM OF THE DESIGN MBIR REACTOR CORE LOADING

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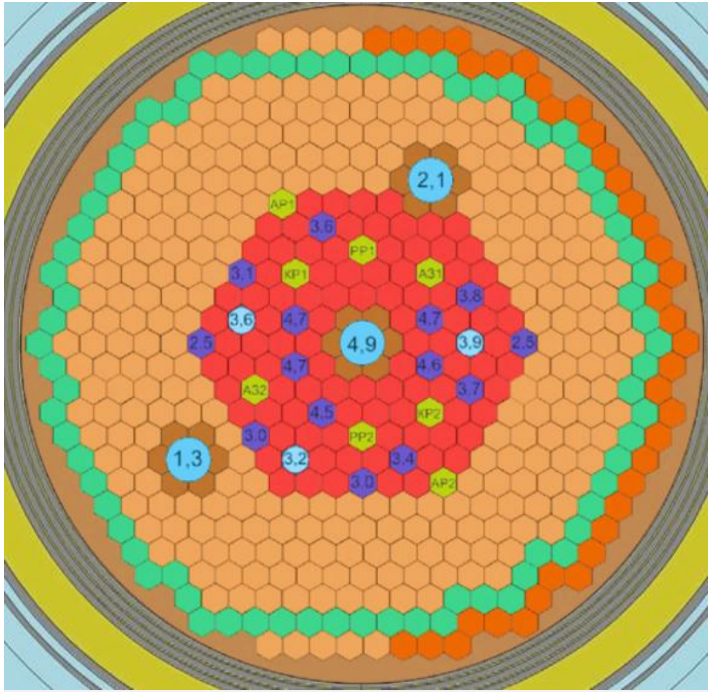
LAYOUT OF MBIR REACTOR CORE WITH PERIPHERY

Neutron Flux is shown with the coefficient 10^{15} sm^{-2} s^{-1}



Fuel Assembly
Control Rod
Test Channel
Material Test Rig / Isotope Production Rig
Blanket Assembly
Spent Fuel Assembly
Shielding Assembly

The following experimental devices can be placed inside the reactor vessel:

- LOOP CHANNELS for modeling the operating conditions of NPP core with various coolants, which are part of independent loop;
- LOOP TEST FACILITY with various coolants (LTF);
- MATERIALS TEST RIG (MTR);
- IRRADIATION TEST RIG (TR)

The project provides for:

1 — Central loop channels (7 reactor cells);

2 — Periphery loop channels (each with 7 reactor cells);

3 — Instrumented loop channels

14 — Non-instrumented channels

2,28 l — Total useful volume of one irradiation cell;

6,92 cm — Internal diameter of the irradiation cell;

55 cm — The height of the fuel column.

EXPERIMENTAL CAPABILITIES OF THE MBIR REACTOR

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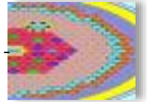
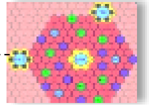
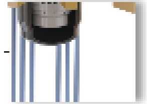
EXPERIMENTAL DEVICE	LOCATION		AMOUNT	SIZE, mm	NEUTRON FLUX IN THE CELL, $cm^{-2} \cdot s^{-1}$
Slots for materials science assemblies & isotopes productions		reactor core	Up to 14	One ready-made cell, 72.2	Max – $5.0 \cdot 10^{15}$ Mid – $3.1 \cdot 10^{15}$
Slots for materials science assemblies & isotopes productions		reactor core, blanket	Limited by blanket size	One ready-made cell, 72.2	
Instrumented irradiation test rigs (ampule channels)		reactor core	Up to 3	One ready-made cell, 72.2	$(3.2 \div 4.0) \cdot 10^{15}$
Independent loop channels with various coolants (Na, Pb, Pb-Bi, gas, salt)		core center, blanket	5 Up to 3 at once	7 standard cells Ø 100	$5.0 \cdot 10^{15}$ $1 \div 2 \cdot 10^{15}$
Horizontal Experimental Channel (HEC)		out-of-core	6	200	$0.5 \cdot 10^{14}$
Vertical Experimental Channel (VEC)		out-of-core	Up to 12 2	~ 350 ~ 50	$0.5 \cdot 10^{14}$

MBIR INDEPENDENT LOOP CHANNELS PARAMETERS

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PARAMETER /LOOP NAME	LCh-Na	LCh-Pb	LCh-Pb-Bi	LCh-Gas (He)	LCh-Salt
Coolant	Sodium	Lead	Lead-bismuth alloy	Gas (high purity helium)	Metal fluorides melt
Neutron fluence in LCh, $cm^{-2} \cdot s^{-1}$	$\geq 3 \cdot 10^{15}$	$2 \cdot 10^{15}$	$(2 \div 3) \cdot 10^{15}$	$(0.4 \div 1) \cdot 10^{15}$	Up to $3.5 \cdot 10^{15}$
Power, MW	Up to 1.0	≥ 0.3	Up to 0.8	Up to 0.15	Up to 0.15
External diameter, mm	≥ 190	≥ 190	≥ 190	≥ 130	≥ 150
Fuel length	MBIR core height	MBIR core height	MBIR core height	Side reflector height	MBIR core height
T_{in}/T_{out} of working fluid, °C	320/550	Up to 350/ up to 750	Up to 350/ up to 500	≥ 950	750/ 800

IRC MBIR CONSORTIUM MEMBERS CAN START THEIR R&D PROGRAMS ON BOR-60 BEFORE MBIR COMMISSIONING

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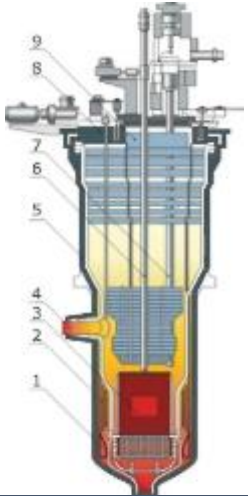
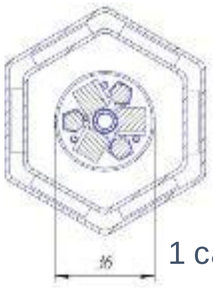
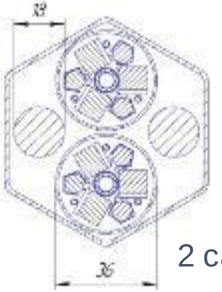


Currently
Research start in the BOR-60 reactor

From 2028
Continuation of R&D in the MBIR reactor



1 capsule



2 capsules

- Possibility to select a BOR-60 cell with approximately the same parameters as in MBIR (neutron flux, density, energy, etc.)
- Comprehensive studies have been carried out, confirming the possibility to continue BOR-60 irradiation in the MBIR (transferring the research program)
- RIAR has a large experience in transferring samples from one BOR-60 assembly to another and continuing irradiation campaign of the samples that were previously irradiated in other reactors

POLYFUNCTIONAL RADIOCHEMICAL COMPLEX (R&D COMPLEX) - NEXT GENERATION NUCLEAR LAB

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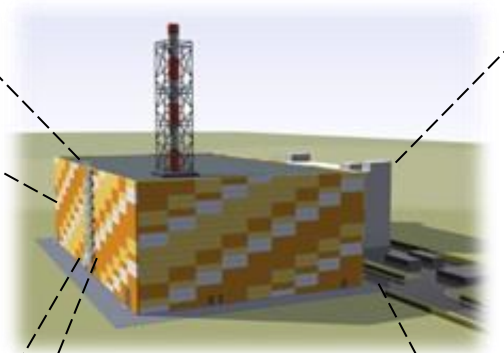
Research throughout the life cycle from FA to fresh fuel and RAW

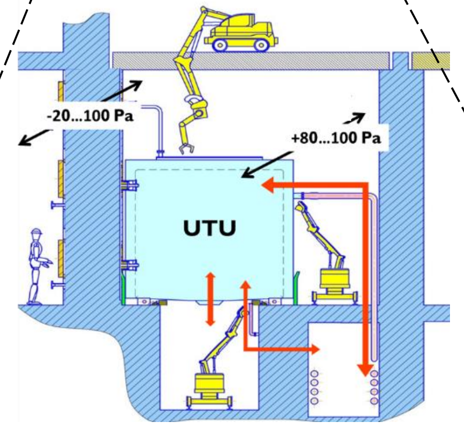
Real FR SNF turnover – up to 600 kg SNF per year

- ✓ Any SFAs from FR, existing and under development (up to 4 meters long)
- ✓ Any fuel composition (oxide, metallic or other)
- ✓ Any burn-up and cooling time (up to 7 kW of residual heat allowed per FA)

Full scale demonstration for all kinds of RAW (on real SNF) reveals the profile of radioactive waste and decrease implementation risk

All RAW handling is carried out by standard R&D Complex systems





The broadest research opportunities

- ✓ from natural uranium to 6-month cooling SNF
- ✓ any actinides (Pu, Np, Am, Cm)
- ✓ from “in vitro” research to real prototype
- ✓ from a few grams to a full-scale demonstration (1 FA in reprocessing with up to 127 kg SNF inside)
- ✓ from bench-top to heavy hot cell (1.3 m concrete wall, up to 15 kg SNF on processing)

Experiments on the controlled storage matrix (glass, ceramic, etc.) with real immobilized RAW for up to 15 years

IRC MBIR

ROSATOM / RIAR

CONSORTIUM IRC MBIR

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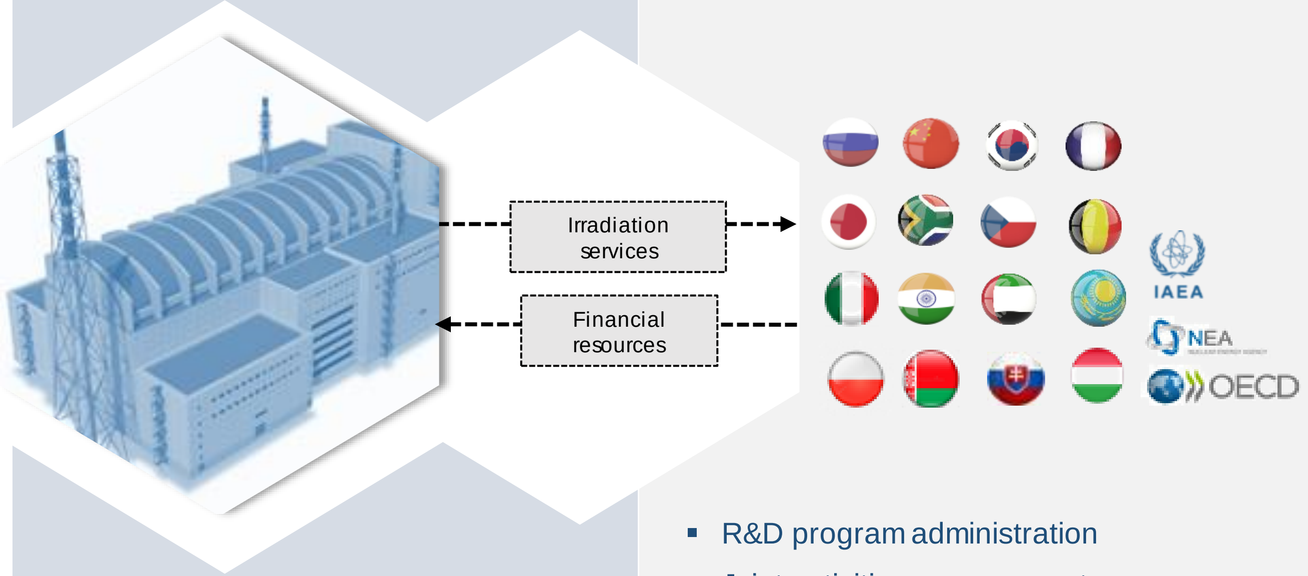
- ROSATOM calls for international cooperation & research partnership based on MBIR reactor
- International experience demonstrates that future breakthrough R&D requires powerful research reactors, which leads to very high cost of such research reactors
- 50% of MBIR reactor resource is intended for the Russian national research program for new reactor technologies research and studies on increase of nuclear industry efficiency
- 50% of MBIR reactor resource can be used by international partners by participating in IRC MBIR Consortium
- Similar or comparable research reactors currently do not exist



- Operating the reactor
- Liabilities, Operation & Maintenance
- R&D program execution
- Laboratory assist

- R&D program administration
- Joint activities management
- Managing of joint financing
- Development and maintenance of the research infrastructure
- Formation of the reactor research market and promotion of the advanced Generation IV technologies and CNCF

PURPOSE AND OBJECTIVES OF THE IRC CONSORTIUM

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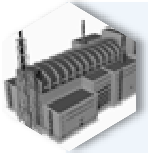
MISSION OF THE IRC MBIR CONSORTIUM

- ✓ Creation of an international scientific platform to address current challenges in the field of innovative nuclear technologies on the basis of MBIR and and R&D complex
- ✓ Providing a full cycle of high-tech knowledge-intensive services: pre-,under- and post-irradiation research of nuclear materials and elements of active zones of existing and prospective nuclear reactors



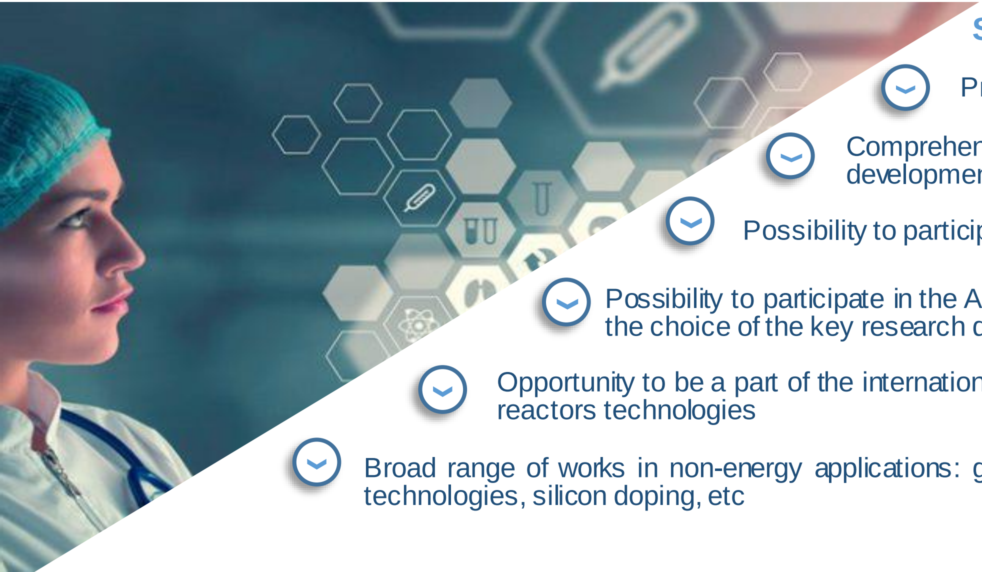
OBJECTIVES OF THE IRC MBIR CONSORTIUM

- Broad scientific collaboration with the participation of the best international experts
- Global center of competence for fast reactors tech under the aegis of OECD NEA and IAEA
- Development of the experimental and rig base for the implementation of international projects and multilateral research programs
- Market formation and promotion of advanced Generation IV reactor technologies and close nuclear fuel cycle
- Best practices and examples of engineering culture in the field of planning, conducting and supporting experiments
- Providing the possibility of free entry, taking into account the subsequent compensation of costs through the implementation of joint scientific programs
- Formation of additional channels to promote the developments and competencies of the scientific platform to world markets

ADVANTAGES FOR FOREIGN PARTNERS JOINING THE IRC MBIR AT THE INVESTMENT STAGE

FINANCIAL BENEFITS

- Competitive and early-bird beneficial pricing model for the MBIR’s reactor resource (~2 times less than at the operational stage)
- The ability to be a regional distributor and profit from resale of the reactor resource (flexible conditions for the transfer of the resource)
- Joining the financial and scientific resources results in the optimal price to quality ratio for the Main users within Consortium compared to creation of national infrastructure
- Savings on national research infrastructure



SCIENTIFIC AND TECHNICAL ADVANTAGES

- Prioritization of science programs
- Comprehensive full-cycle research for strategic decision-making on the launch and development of national programs
- Possibility to participate in the configuration of the research equipment
- Possibility to participate in the Advisory committee (scientific body of the IRC MBIR) as an expert, contributing the choice of the key research directions for the multilateral research programs
- Opportunity to be a part of the international scientific and expert community – key knowledge holder for the fast neutron reactors technologies
- Broad range of works in non-energy applications: general physics research, neutron capture boron therapy, isotopes production technologies, silicon doping, etc

FINANCING STATUS OF MBIR AND R&D COMPLEX PROJECTS

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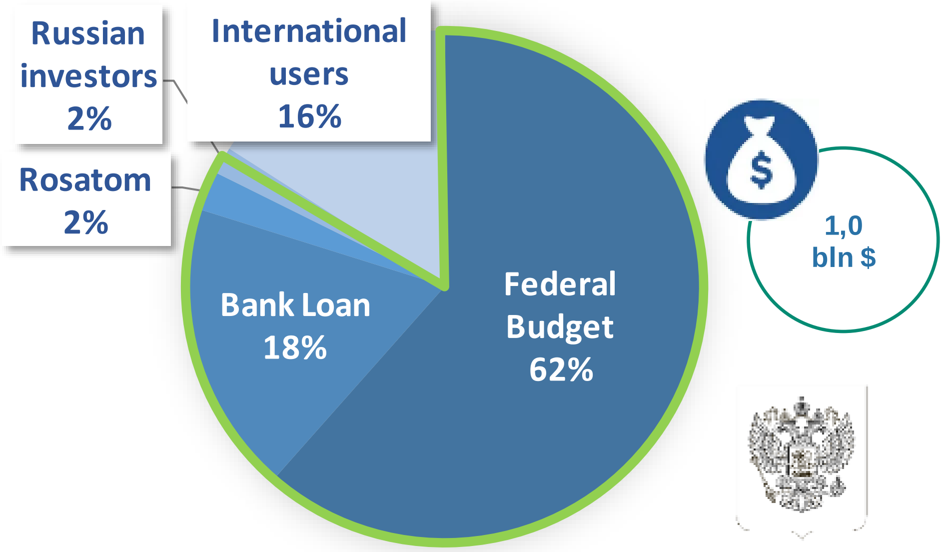
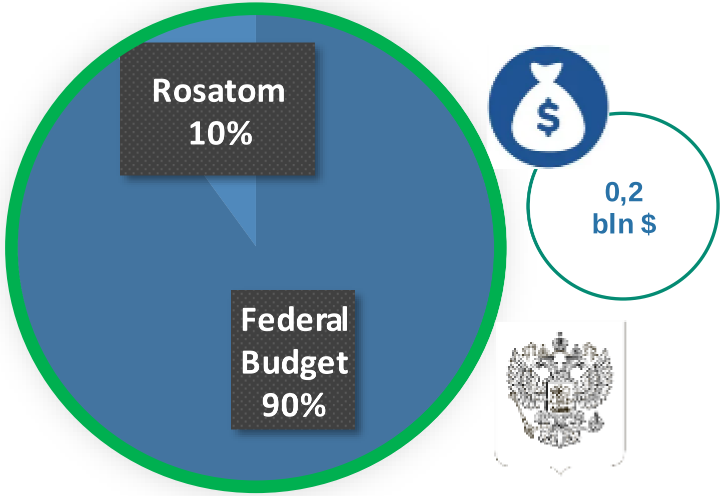
MBIR Reactor

Russian government has decided to increase the share in MBIR CAPEX and include IRC MBIR into Russian Federal Budget Funding Program. The State share will amount to 71,7 bln Russian rubles (~1 bln USD)



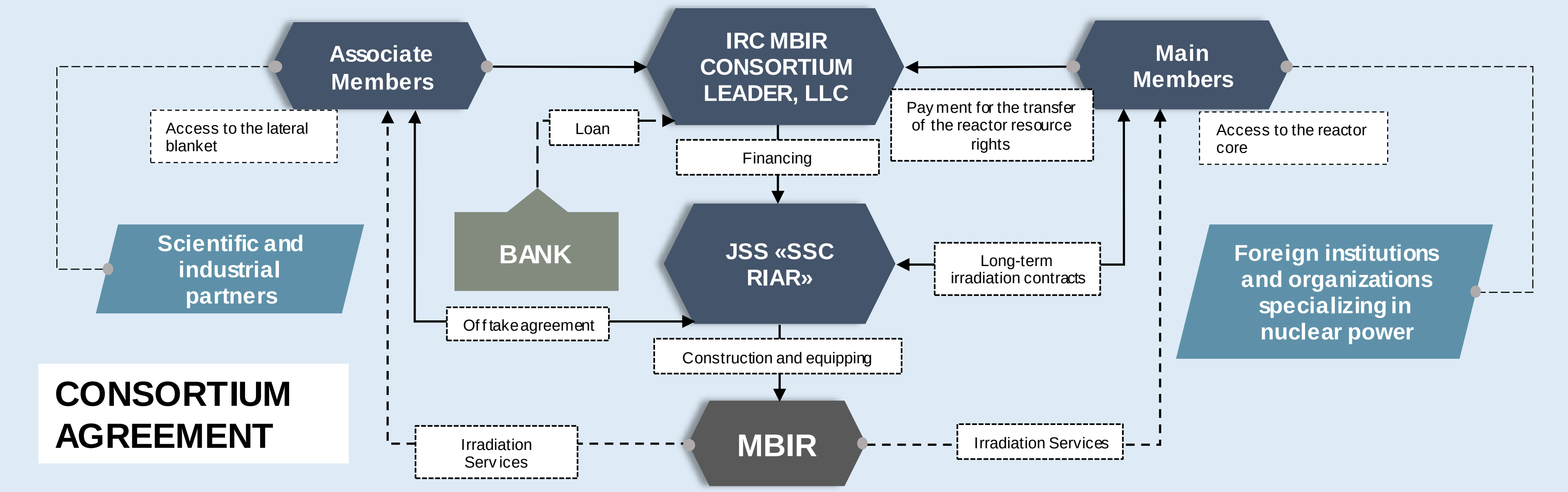
R&D Complex

R&D Complex has all the CAPEX financing covered by Federal Budget of Russian Federation and Rosatom



CONSORTIUM MANAGEMENT STRUCTURE AND TYPES OF PARTICIPATION

There will be different forms of participation and conditions based on the access to the core or lateral blanket and participation in the financing of the reactor construction. The general research program, including the distribution of participants' resources and the formation of multilateral programs, will be formed by the Advisory Council, which will include representatives of the founding members of the IRC, permanent participants of multilateral programs, representatives of the operating organization and independent experts representing leading scientific institutions and industry-specific regional and international organizations.



The consortium agreement defines the relationship between the members and secures a share in the reactor resource (neutron flux), depending on the member's contribution amount. Associate and main members have to join the Consortium by signing the Consortium Agreement and accept its rules in order to conclude an irradiation services contract. IRC MBIR Consortium Leader is responsible for financing the difference between the cost of the reactor and the raised funding from the members of the Consortium, federal budget and ROSATOM.

ROADMAP TO JOIN IRC MBIR

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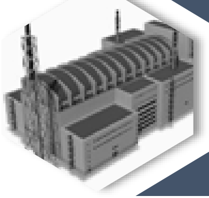
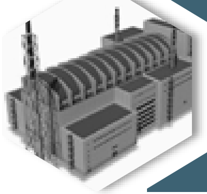
STEP 3



To sign the terms of participation

To conclude a consortium Agreement

STEP 2



To sign a Memorandum of Understanding & non-disclosure agreement

To decide on your scientific program

To select representatives to Consortium management bodies

STEP 1

Letter of Intent with research program directions

Select a Business Partnership type

KEY REASONS TO JOIN IRC MBIR CONSORTIUM

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Reactor complex MBIR is a unique tool for the technologies of the future and also for the experimental studies for improving the technologies of the present.

The Main Members will have the opportunity to define the configuration of the reactor core, prioritize the research equipment (independent loop channels) and chose the cells in the core which suit best its R&D goals.

Merging financial and scientific resources guarantees the best price per quality ratio vs the national research centers and ensures savings on national research infrastructure.

Joining the Consortium as a Main Member at the construction stage guarantees a significant discount on the commercial price of the MBIR reactor resource.

There are no restrictions for the Main Members to further sell the MBIR reactor resource to other users

Establishment of the wide scientific platform with the participation of the leading Russian and international experts.

Opportunity for International partners to ensure the continuity of their R&D (in case of absence or temporal shut down of their own research reactors) and additional experimental possibilities and reactor resource for justifying strategic decisions on development of the national nuclear research programs.

RIAR - the operator with 60-years of research reactor managing experience and on-site supporting facilities guaranty safe and due performance of the reactor and highest quality of experiments execution.

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APPENDIX

EXPERIMENTAL CAPABILITIES – MATERIALS TEST RIG (MTR)

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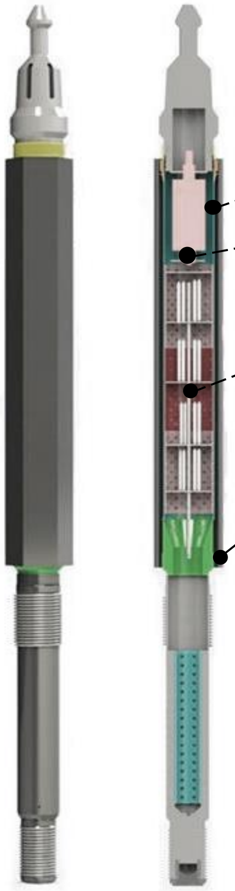

There are four (4) design options of the materials test assembly depending on the shape of inner duct (round or hexahedral) and sodium circulation at the inlet (from the high-pressure and low-pressure chambers).

The design engineering of materials test assembly (MTA) is performed based on the technical requirements specified by the Customer to fulfill irradiation test objectives.

MTR design provides for continuation of irradiation testing launched in the BOR-60 reactor. Two full-size BOR-60 irradiation rigs can be accommodated within the MBIR shroud.

Value	Parameter
72.2	**Width across flats,** mm
2700.0	**Height,** mm
2280.0	**MTR usable volume,** cm^3
14	**Number of MTR** (core)
No more than 36	**Number of MTR** (1st circle of blanket)
20/24	**Dose rate in the core,** dpa/year*
14/17	**Dose rate** (1st circle of blanket), dpa/year*
1.5×10^{23}	**Maximal neutron fluence,** (En > 0.1 MeV), cm^{-2}

** provided that the MBIR capacity utilization factor is 0.65*

EXPERIMENTAL CAPABILITIES– LOOP TEST FACILITY (LTF)

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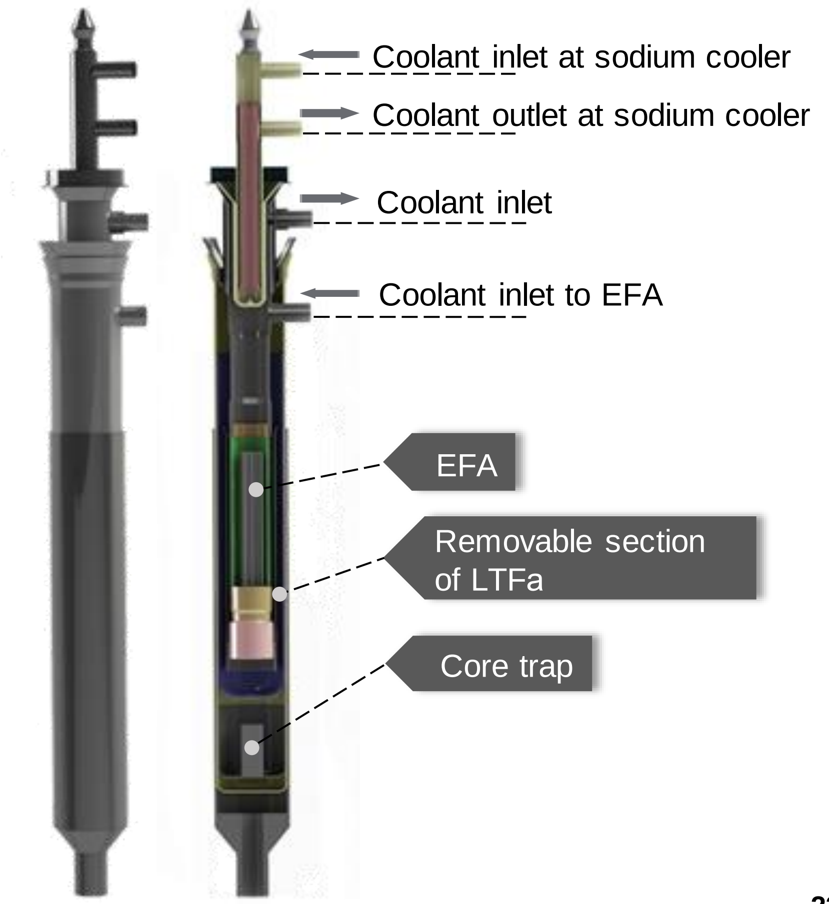
Value	LTF parameter*
11900	**Overall height of LTF,** mm
100	**Outer diameter of LTF** (at the core level), mm
Up to 600 / Up to 900**	**EFA coolant temperature** (at the inlet/at the outlet), °C
Up to 600	**Coolant temperature at the LTF outlet,** °C
550	**EFA fueled length,** mm
Up to 2.85	**Sodium flow rate through the EFA,** kg/s
14/17	**Sodium flow rate through main circuit of LTF,** kg/s

** These parameters are given for sodium-cooled LTF*
*** Coolant boiling operating conditions.*

Value	FA parameter
47,0	**EFA width across flats,** mm
1245	**FR length,** mm
Up to 1100	**Power output,** kW



EXPERIMENTAL CAPABILITIES – IRRADIATION TEST RIG (TR)

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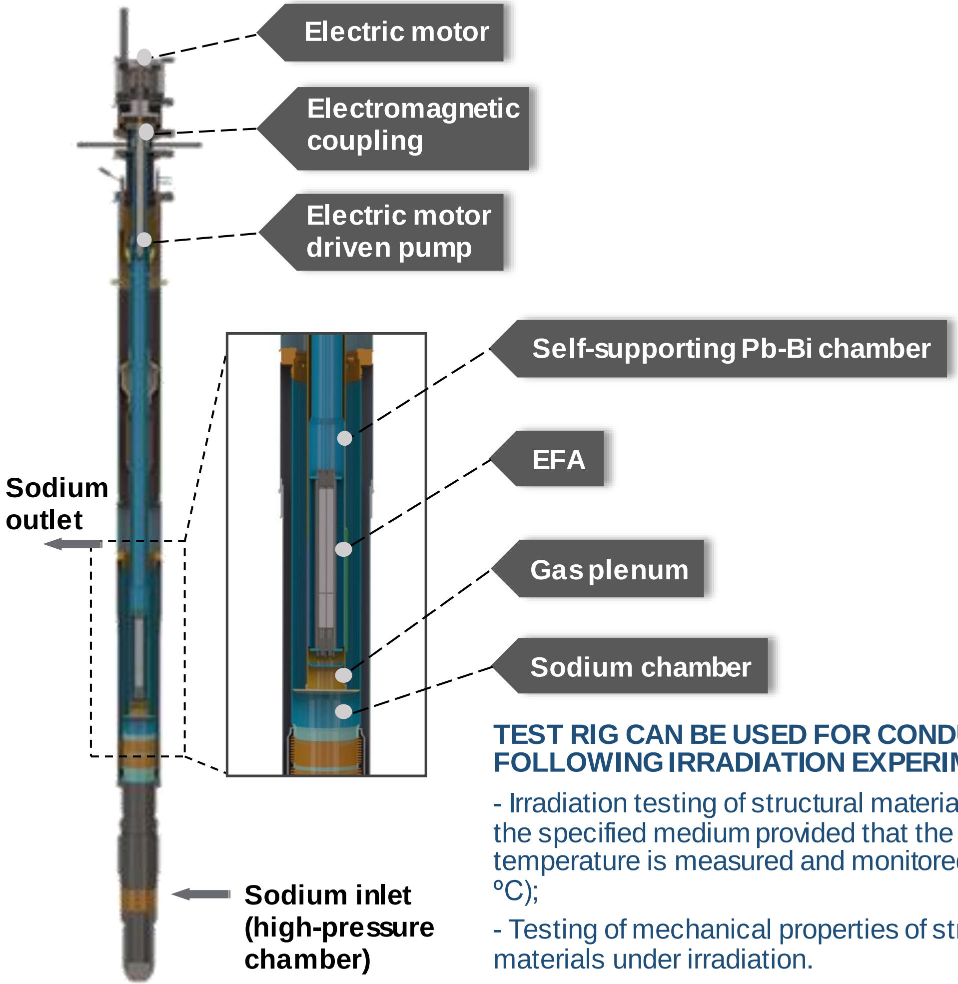

Value	Parameter of Pb-Bi TR
10890	**Overall height of LTF,** mm
72.2	**Width across flats,** mm
68.0 / 65.0	**Outer / inner diameter of cylinder-shaped end cap at the level of the core,** mm
Up to 6.0	**Coolant flow rate through the Pb-Bi chamber,** kg/s
390±10	**Maximum coolant temperature** (in the self-supporting Pb-Bi chamber), °C
45.0 / 41.0	**Outer/inner diameter of FA,** mm

TEST RIG CAN BE USED FOR CONDUCTING THE FOLLOWING IRRADIATION EXPERIMENTS:

- Irradiation testing of structural materials and fuels in the specified medium provided that the irradiation temperature is measured and monitored (320÷1800 °C);
- Testing of mechanical properties of structural materials under irradiation.

THE DESIGN ENGINEERING OF INSTRUMENTED TEST RIGS (ITR)

is performed based on the technical requirements specified by the Customer to fulfill irradiation test objectives.

EXPERIMENTAL CAPABILITIES – HTC AND VTC

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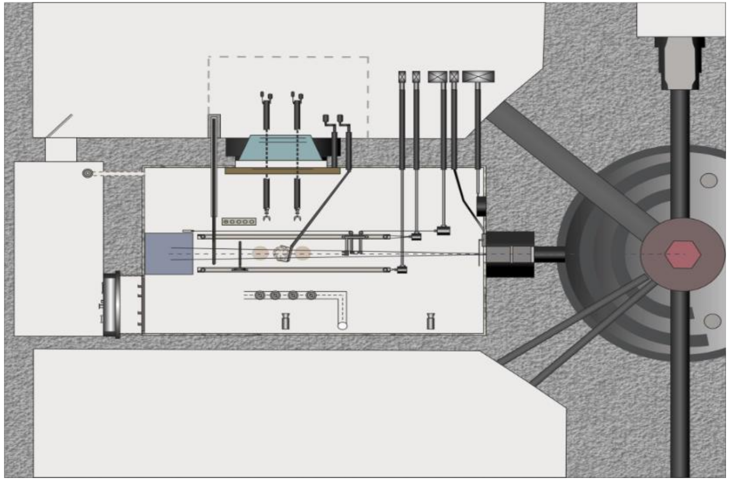
HORIZONTAL TEST CHANNELS (HTC)

There are 6 horizontal test channels for the following activities:

- Neutron radiography
- Nuclear physics experiments
- Medical purposes

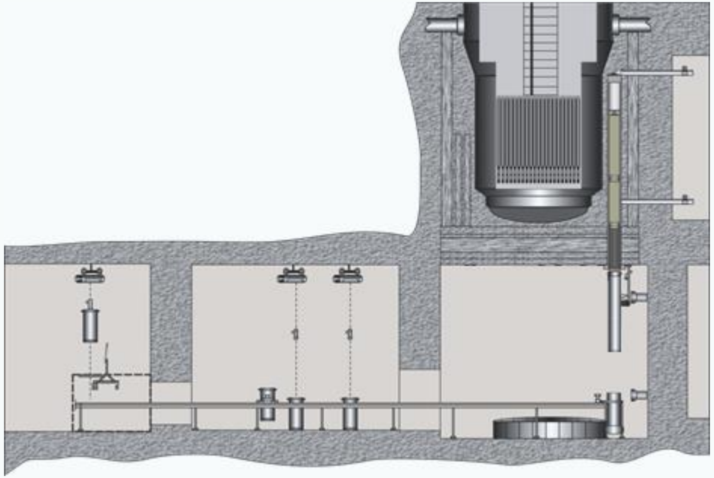


Neutron radiography cell
7.1 m (length) × 4.1 m (width) × 2.9 m (height)

VERTICAL TEST CHANNELS (VTC)

There are 8 vertical test channels for the following activities :

- Silicon doping (6 VTCs.)
- Neutron-activation alalysis (2 VTCs)



Silicon doping facility