NRC KI

PNPI NRC KI

JINR

RUSSIA NEUTRON LANDSCAPE

V.L. Aksenov
Petersburg Nuclear Physics Institute NRC KI (Gatchina)
Joint Institute for Nuclear Research (Dubna)

International Conference Nucleus -2015, 30th June 2015, St.-Petersburg

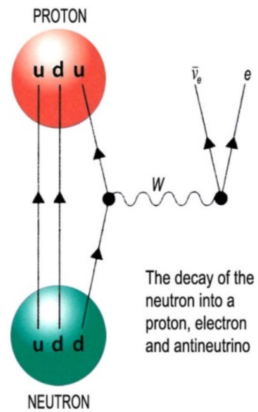
Neutrons in Partical and Nuclear Physics
(modern trends)

Neutrons and New Physics

Early Universe : τ_n

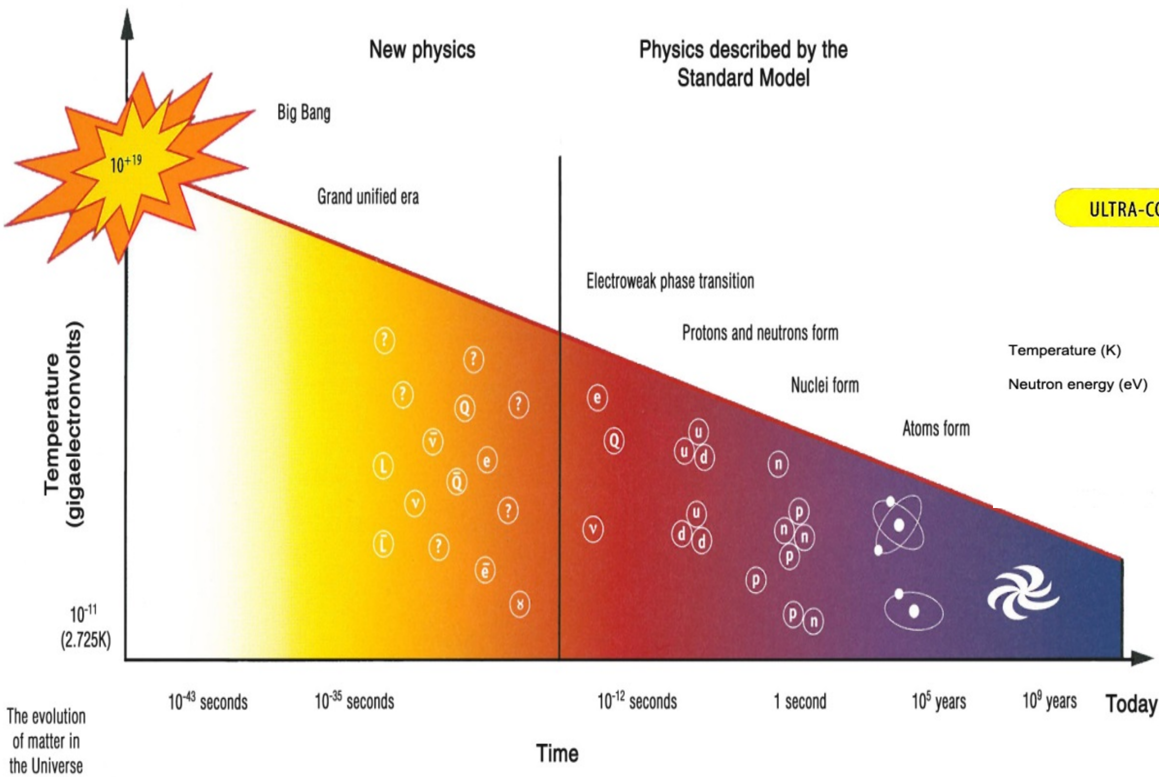
Bargon asemmetry : EDM

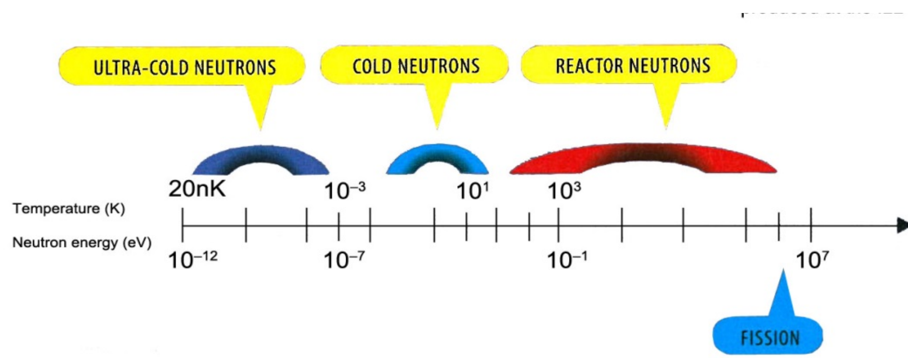
Lef-right symmetry : (n, α)



Dark energy
Dark matter } UCN gravity resonance spectroscopy

Quantum mechanics
(Schrodinger and Cheshire cats) } UCN





Neutrino Physics

Understanding of the nucleus

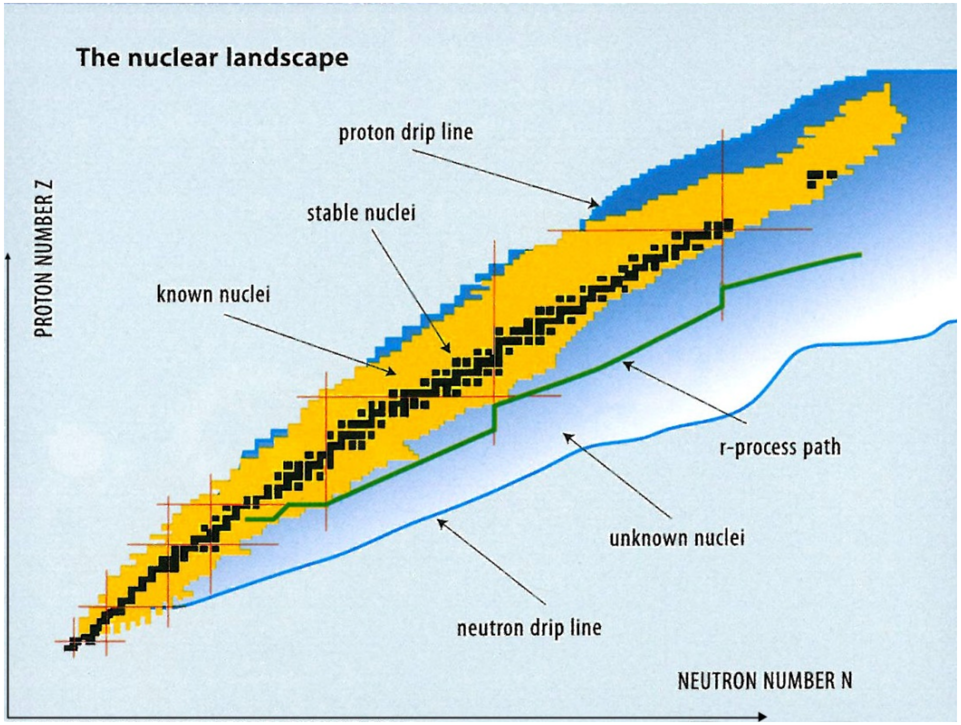
Nuclear Structure
(nuclear models)

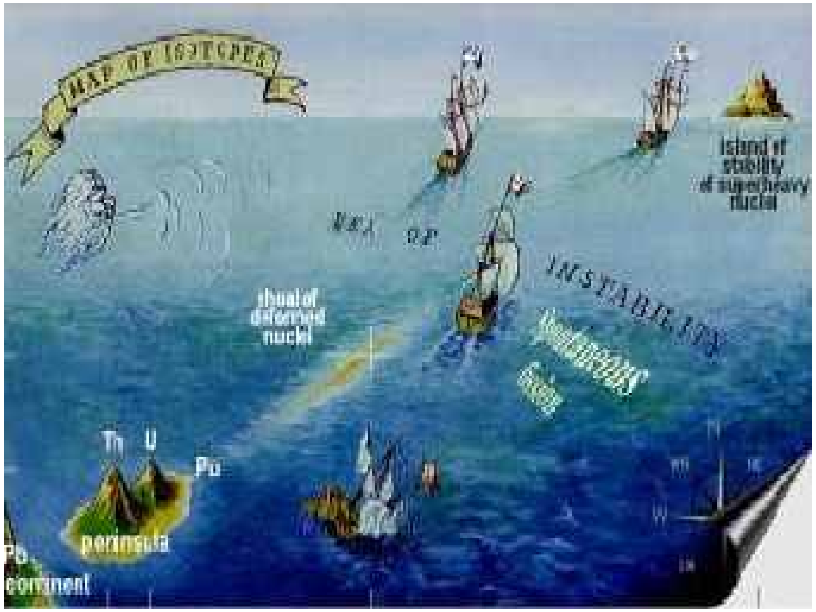
Probing exotic
(n-rich) nucleus

Phase Transitions
in nuclei

Fission Physics

Duclear Data





Astrophysics
(where do the heavy
elements come from?)

red giant stars (s-process)

super nova (r-process)

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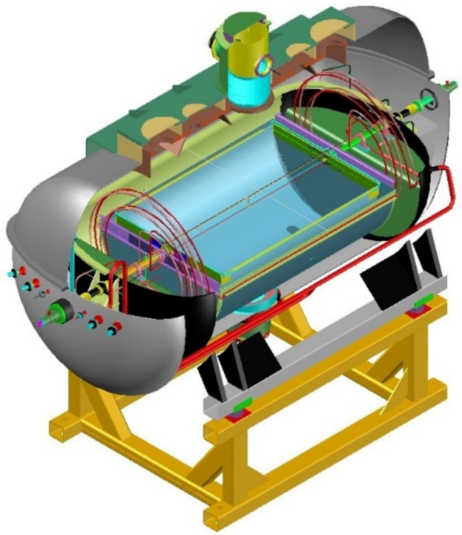
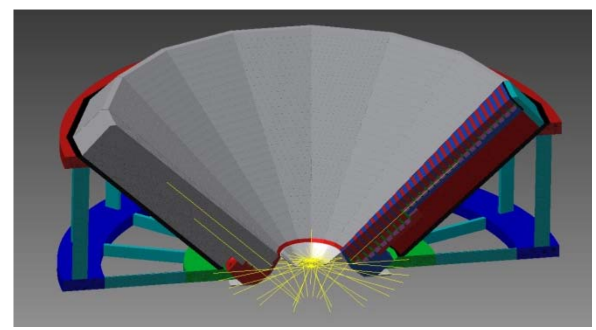
New generation of neutron lifetime experiments

Big Gravitrap

τ_{beam}-τ_{ucn}=8.4(2.2)s (3.8σ)



Magnetic trap



Goal: to reach accuracy **0.2 sec** by the **storage of neutron in material trap**

Goal: to reach accuracy **0.2 sec by magnetic storage of neutron**

A.P. Serebrov and A.K. Fomin, Physics Procedia 17 (2011) 199–205

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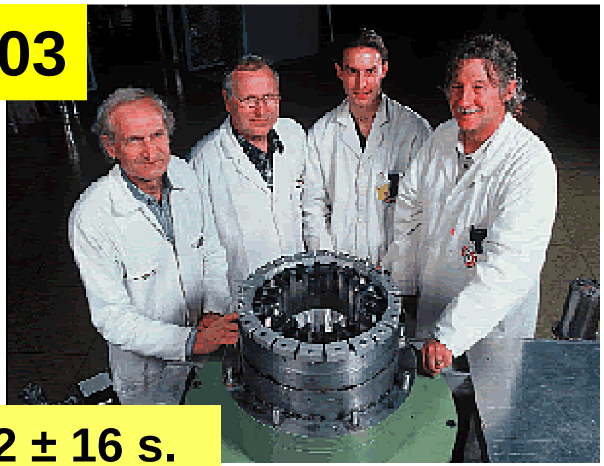
UCN magnetic storage and neutron lifetime PNPI-ILL

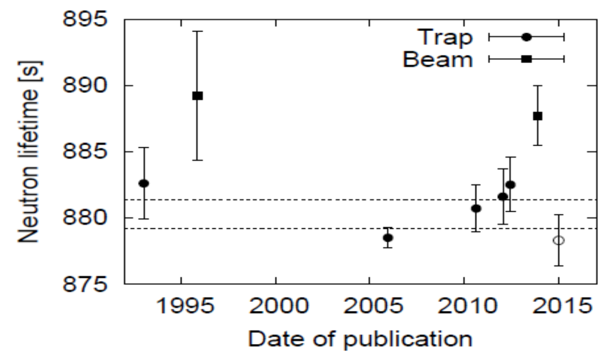
First trap of permanent magnets

2003



882 ± 16 s.

2014

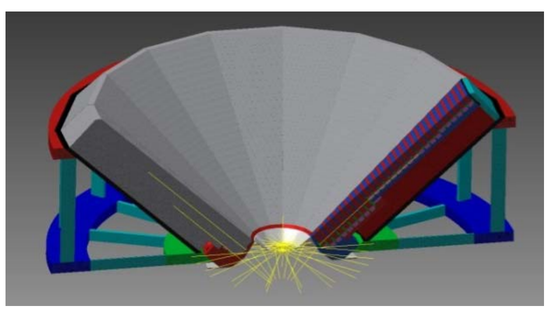


τ_n=(878.3±1.9) s.

(Submitted on 23rd of Dec 2014)
arXiv:1412.7434 [nucl-ex]

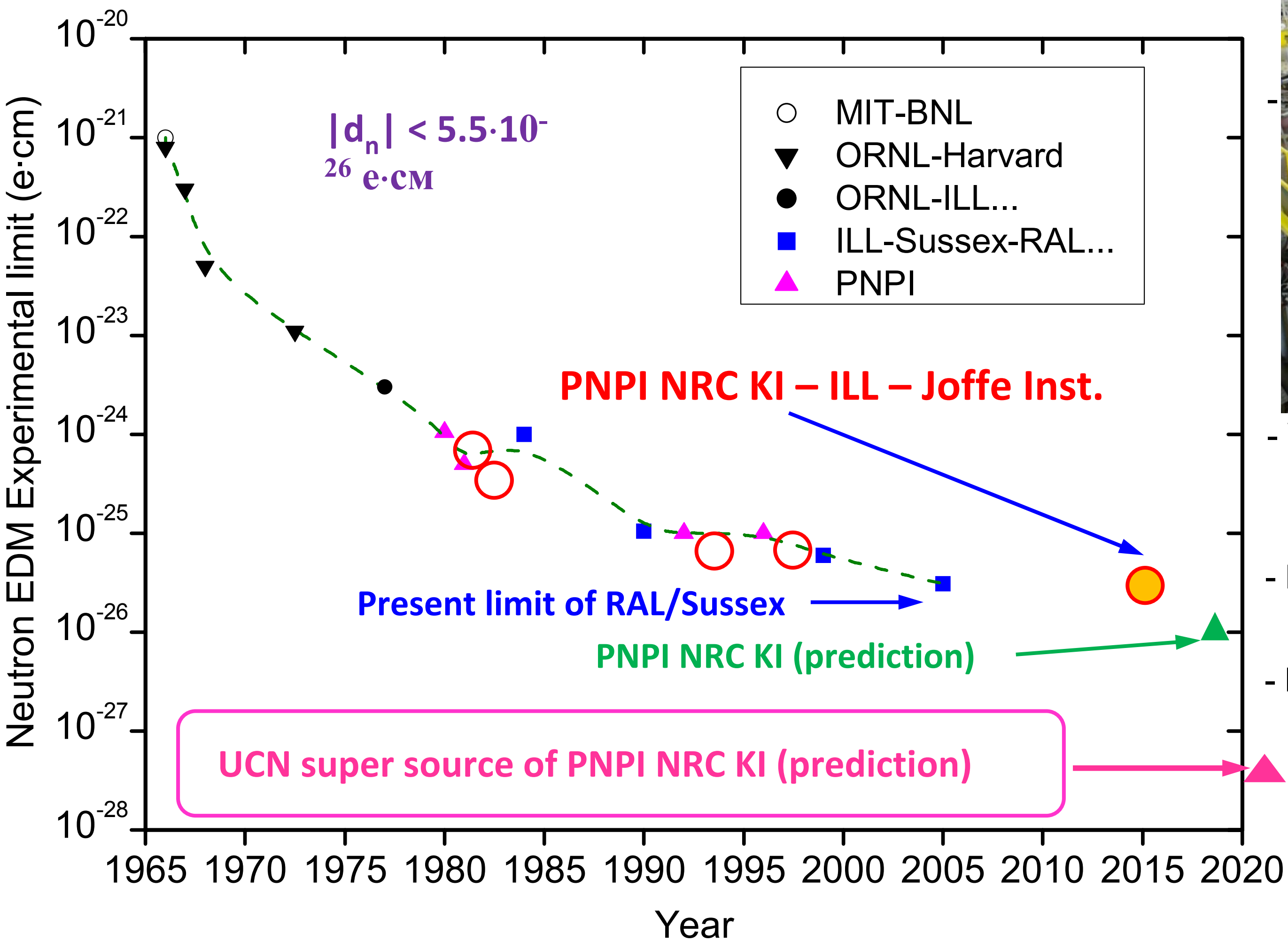
2015 -

New trap of permanent magnets



expected accuracy 0.2 s

Neutron electric dipole moment



A.P. Serebrov, et al., JETP Letters, 99, pp. 4–8, (2014)

The study of the P-odd asymmetry in the alpha-particle emission in the reaction $^{10}B(n,\alpha)^{7}Li$

Yu.M. Gledenov[1], V.V. Nesvizhevsky[2], P.V. Sedyshev[1], E.V. Shulgina[3], P. Szalanski[4], V. A. Vesna[3]
[1] JINR, Dubna, Russia, [2] ILL, Grenoble, France, [3] NRC "KI" PNPI, Gatchina, Russia, [4] LU Lodz, Poland

P-odd asymmetry in the reaction **$^{6}Li(n,\alpha)^{3}H$** was measured at PF1b at the ILL reactor:

$$a_{P\text{-odd}} = (-8.8 \pm 2.1)\times 10^{-8}$$

Constrains for the neutral weak constant :

$0 \le f_\pi \le 1.1\times 10^{-7}$ **(at 90% confidence level)**

Goal: To reach the accuracy of P-odd asymmetry in the reaction **$^{10}B(n,\alpha)^{7}Li$**

$\sim 5 \times 10^{-8}$.

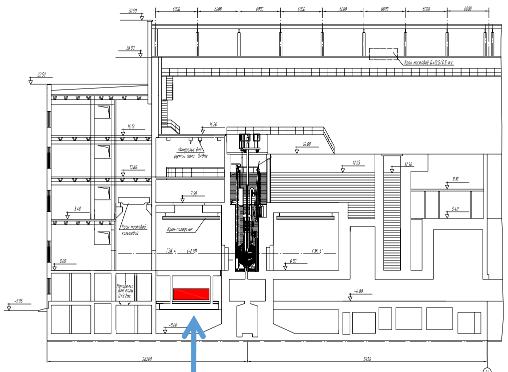
Beam time is approved for PF1b instrument
cycle n° 176-177

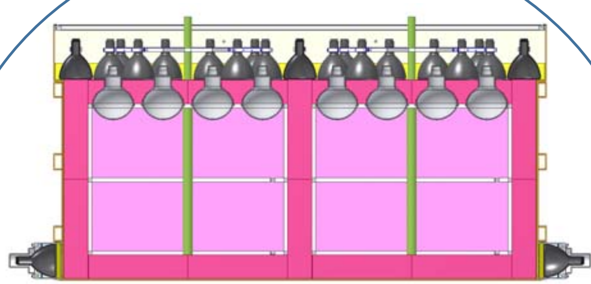
Experiment "NEUTRINO-4" $\bar{\nu}_e + p \rightarrow e^+ + n$

PNPI NRC KI (Gatchina), NRC KI (Moscow), NIIAR (Dimitrovgrad)

reactor PIK (Gatchina) – project

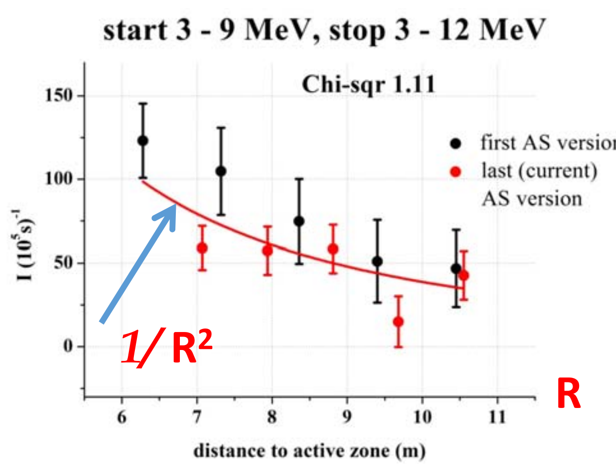
reactor SM-3 (Dimitrovgrad)





Liquid scintillator detector ***3 m^3***
+ FEM ***64 pcs.***

Laboratory for sterile neutrino. The distance for observations of reactor antineutrino oscillations is in the interval of 6–12 meters from the reactor core .

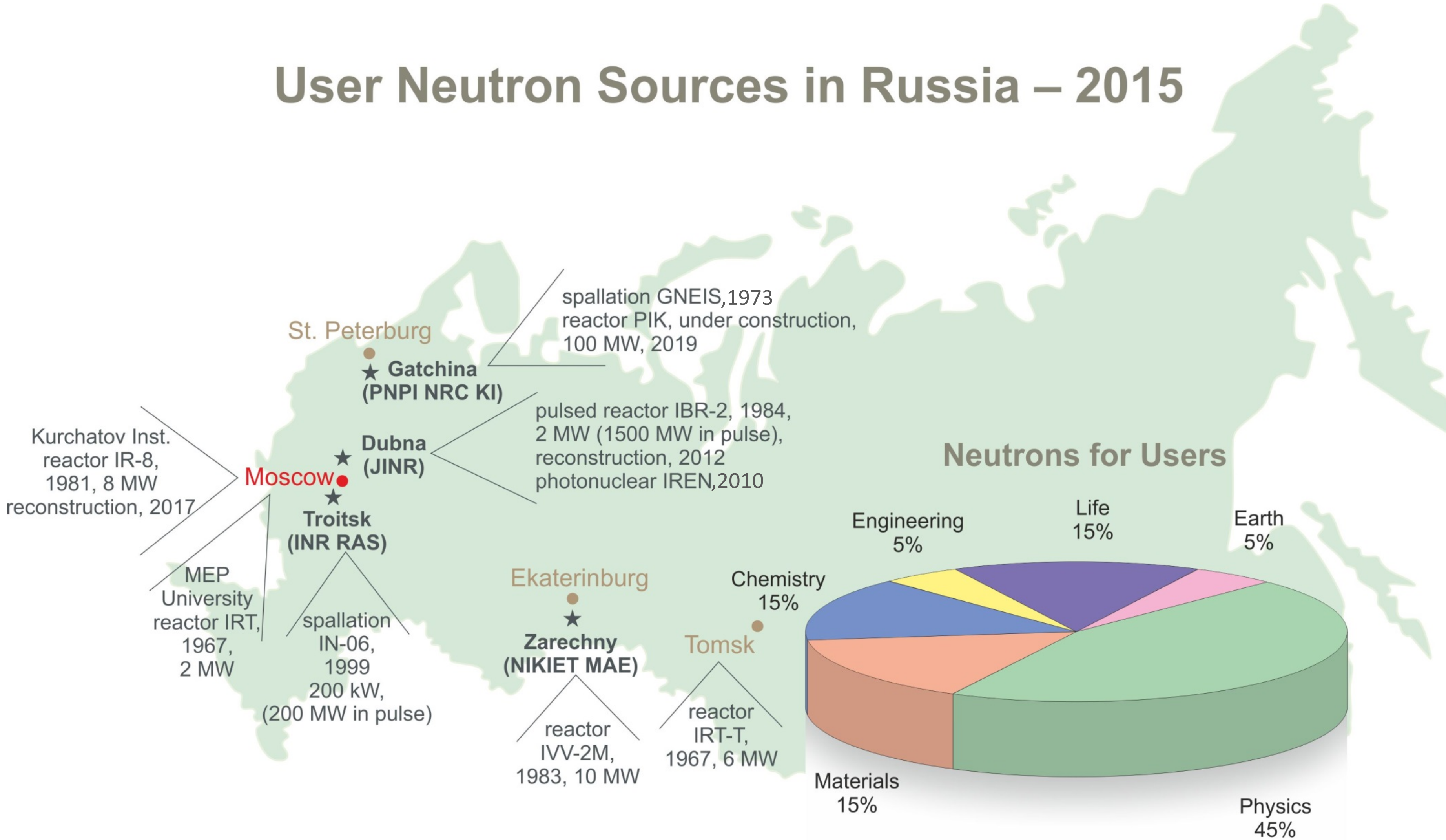


First measurements

Neutrino channel

Neutron Sources in Russia

User Neutron Sources in Russia – 2015



Strategy Paper on Neutron Research of National Research Center “Kurchatov Institute” and Joint Institute for Nuclear Research

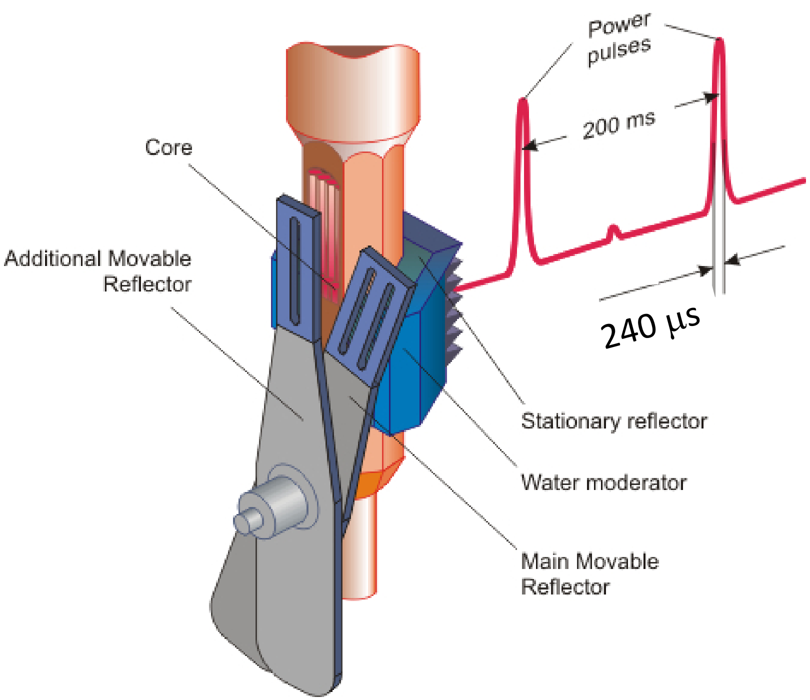
Pulsed sources

IBR-2 (JINR, Dubna)	:	2012 ÷ 2037
IREN (JINR, Dubna)	:	2010 ÷ 2045
GNEIS (NRC KI, Gatchina)	:	1973, life time? proton synchrocyclotron, 1GeV, 1971

Stady state

VVR-M (NRC KI, Gatchina)	:	shutdown mode, 2016
IR-8 (NRC KI, Moscow)	:	2007 ÷ 2017 upgrade
PIK (NRC KI, Gatchina)	:	2019 ÷ 2049

Modernized IBR-2 High Flux Pulsed Reactor (FLNP JINR)



Information: http://flnp.jinr.ru/34/

Virtual excursion: http://uc2.jinr.ru/pano/lnf/

Operational since 1984

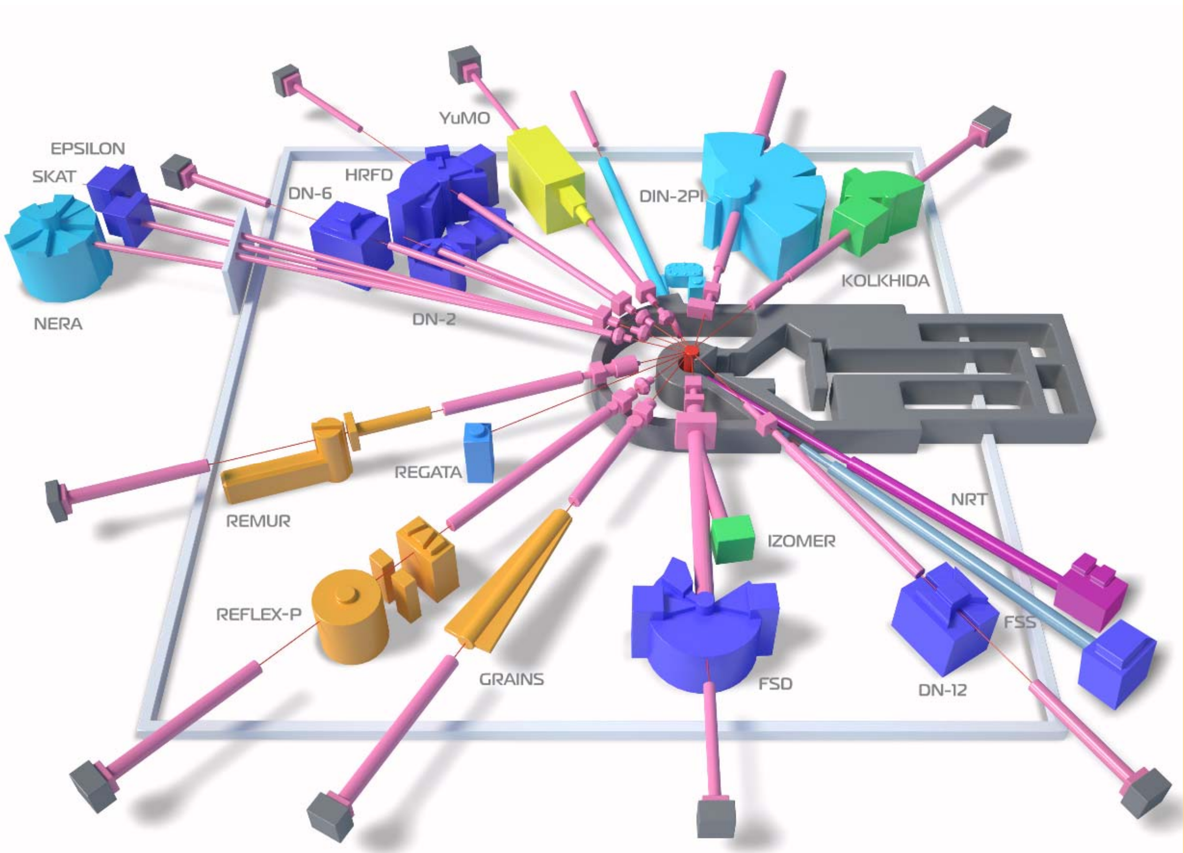
2007- 2010: modernization shutdown

2010 – 2011 Physical and power start-up completed

2012 – Regular operation renewed

By D.P. Kozlenko, FLNP, Dubna

IBR-2M Spectrometers Complex



2011:
11 instruments in operation

→

2014:
14 instruments in operation

Diffractometers:

HRFD, DN-12, FSD, SKAT/Epsilon

Reflectometers:

REMUR, REFLEX

Small Angle Scattering Spectrometer: YuMO

Inelastic Neutron Scattering Spectrometers:

NERA-PR, DIN-2PI

New Instruments:

DN-6. GRAINS, NRT

Reconstruction:

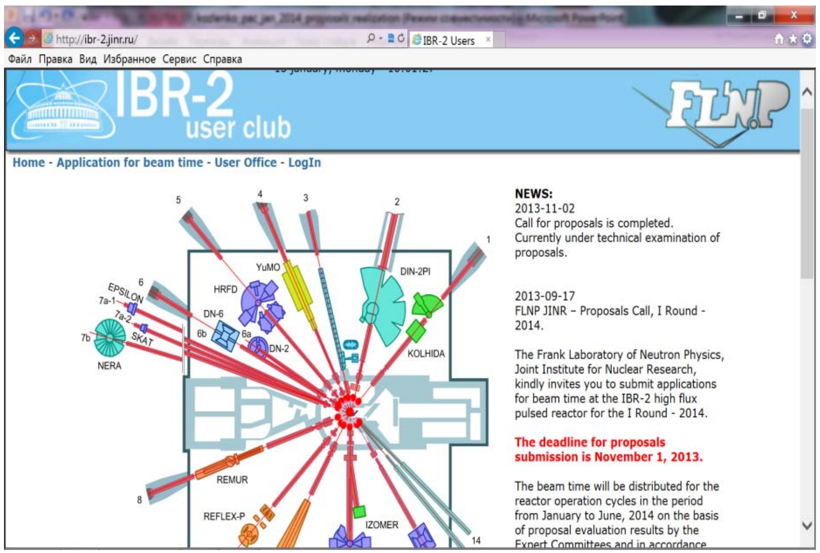
DN-2 – RTD,

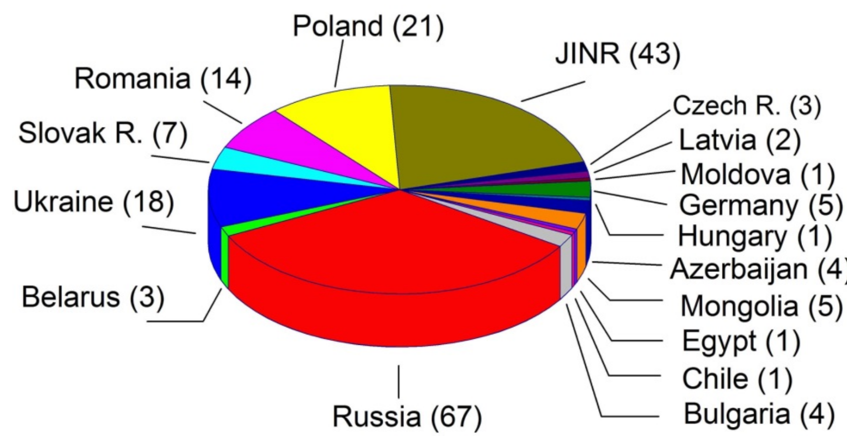
REFLEX - SESANS

User Programme at IBR-2 instruments:

Two calls of proposals per year with deadlines 15 April and 15 October

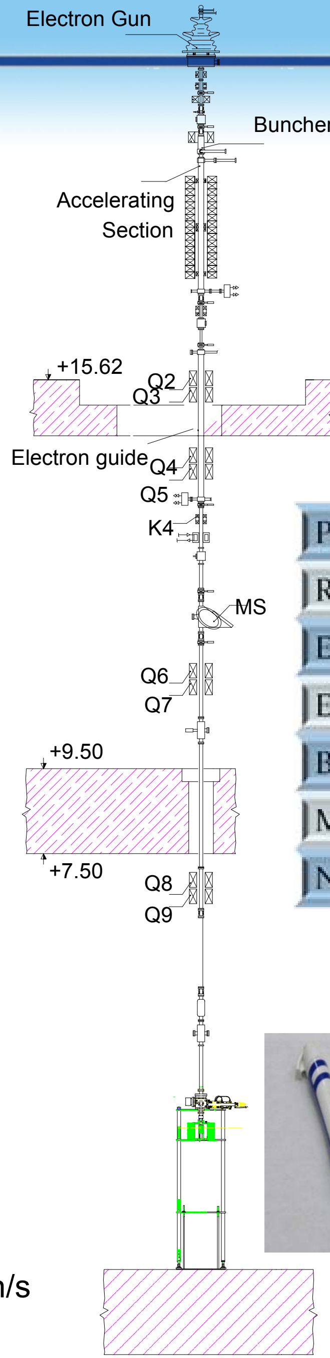
Applications are collected via web-site http://ibr-2.jinr.ru





200 applications from 16 countries were received in 2014

IREN facility
(Intense REsonance Neutron source)



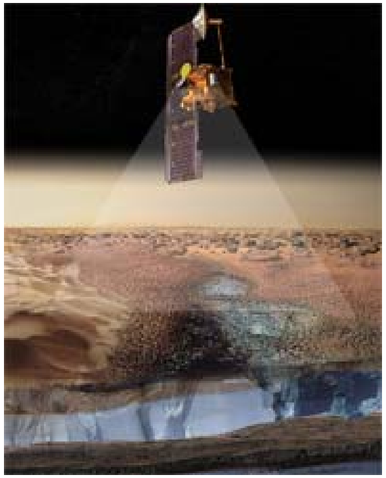
Peak current (A)	3
Repetition rate (Hz)	50
Electron pulse duration (ns)	100
Electron energy (MeV)	30
Beam power (kW)	0.4
Multiplication	1
Neutron intensity (n/s)	10^{11}

IREN planned parameters

Pulse duraion: 20-200 ns
Peak current: 3 A
Repetition rate: 150 Hz
Average current: up to 50 rrkA
Electron energy: up to 200 MeV
Beam power: up to 10 kW
Target : ^{238}U
Integral neutron yield: up to 3.4×10^{13} n/s

Fundamental

- Fundamental symmetries in neutron induced reactions
- Nuclear Data
- Nuclear fission
- Fundamental properties of the neutron
- Highly excited states of the nuclei



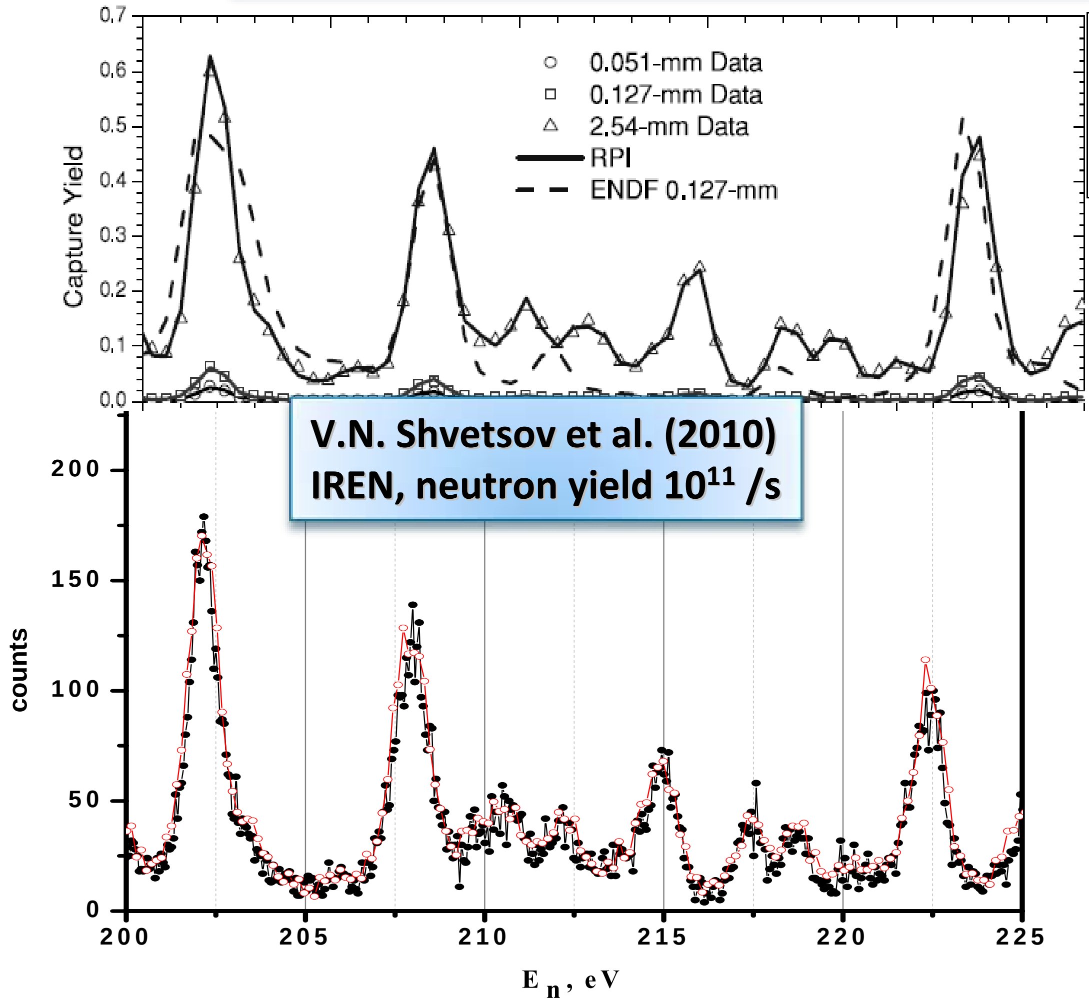
Applied

- Isotopes production
- Neutron activation analysis
- Nuclear in space

Nuclear data at IREN – first measurements with Gd_{nat}

G. Leinweber et al., Nucl. Sci. Eng., 154 (2006) 256

RPI Linac, neutron yield 10^{12} /s



V.N. Shvetsov et al. (2010)
IREN, neutron yield 10^{11} /s

^{nat}Gd (n, γ)

^{152}Gd - 0.20%
^{154}Gd - 2.18%
^{155}Gd - 14.80%
^{156}Gd - 20.47%
^{157}Gd - 15.65%
^{158}Gd - 24.84%
^{160}Gd - 21.86%

Sample:
m_g = 172.8 g
size: 11.2 x 14.5 cm^2
ρ: 1.064039 g/cm^2
d: 1.35mm

IREN, Dubna
f = 25 Hz
I_e = 2A; t_e=100ns
L = 58.6m

dt= 100ns
t_{mes} = 14h40’
dt= 40 ns
t_{mes} = 19h00’

Reactor Complex PIK

Central part of the reactor complex PIK

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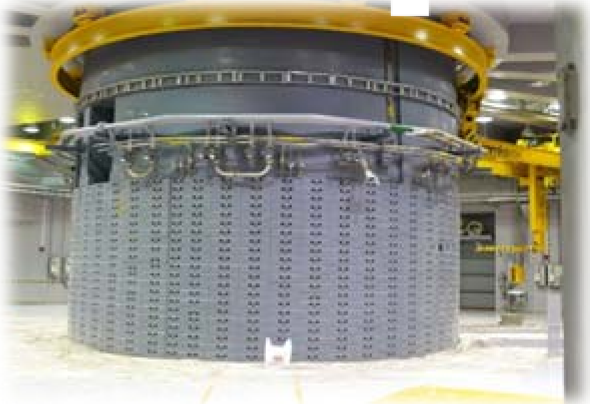
Reactor Complex PIK

Start up complex №1.
Facilities of reactor complex PIK for the first criticality
(commissioned in 2009)



2011 a critical state of the fuel assembly was achieved and a complete test of the reactor systems was produced without coolant at W = 100 W

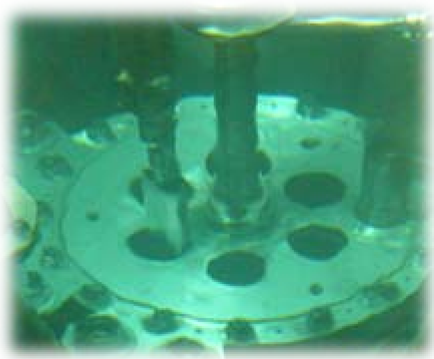
INVESTMENT PROJECTS PNPI NRC KI 2014-2020

Projects for the building of the research reactor complex PIK

Modernization of engineering infrastructure of the reactor complex PIK
(commissioning in 2018)

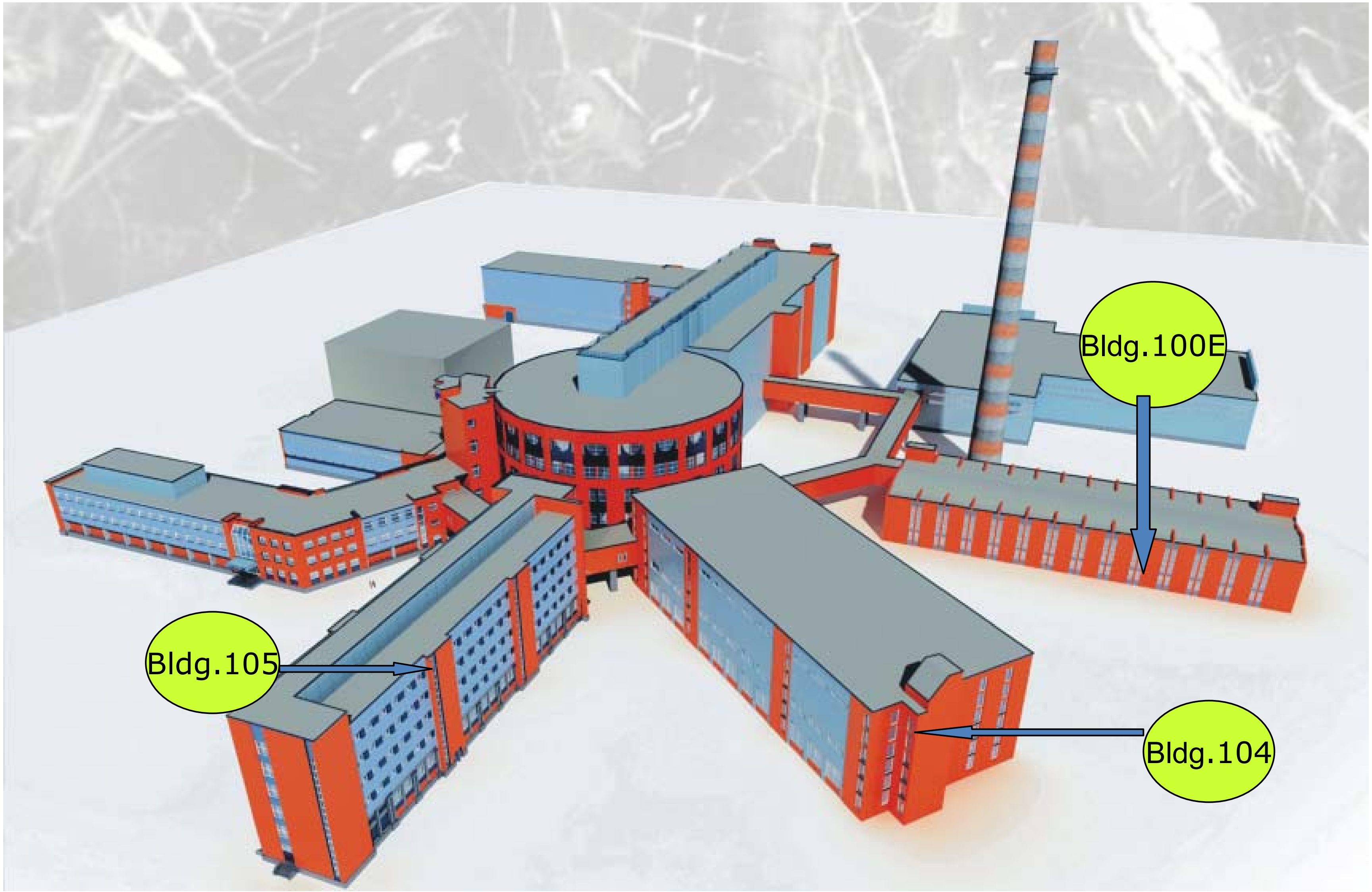
Reconstruction of laboratory complex PIK
(commissioning in 2019)

Instrumentation program of the reactor complex PIK
(commissioning in 2020)



Reconstruction of the Laboratory Complex PIK

Buildings of the reactor PIK reconstructed during the project

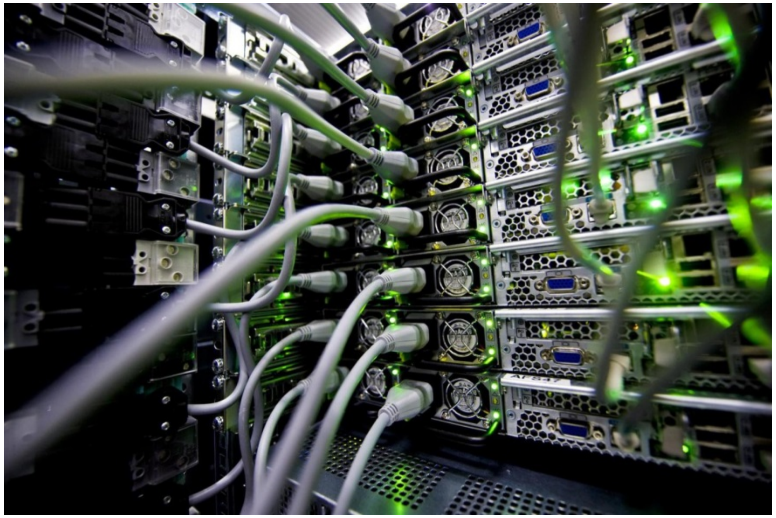


Reconstruction of the Laboratory Complex PIK

Buildings of the Laboratory Complex

Computer Information System Tier-0 of the reactor PIK (analog to CERN Data Centre)

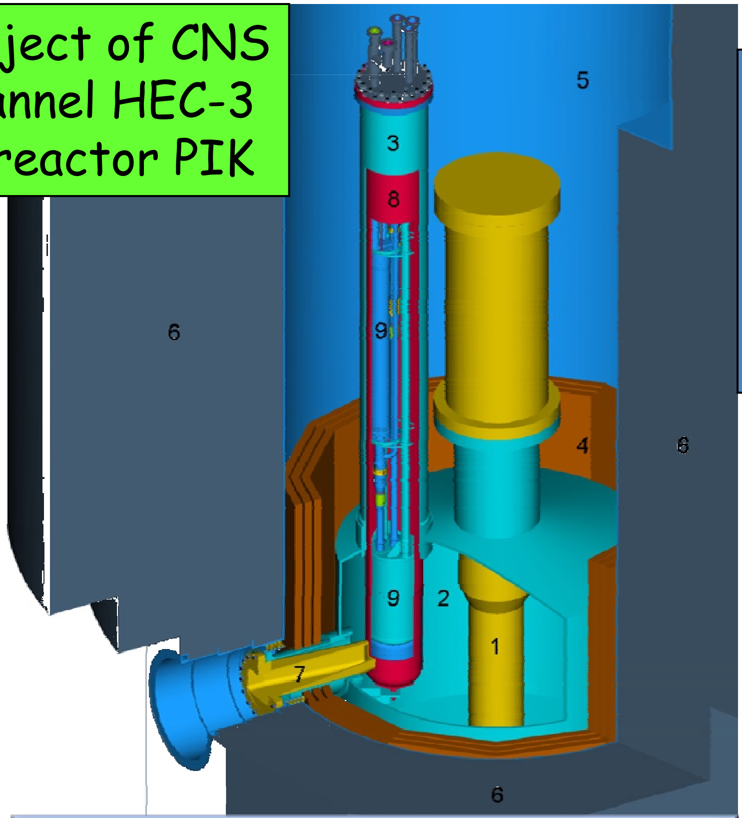
- Creating computing power with a speed of about 100 teraflops for data processing and data storage.
- Creating a data collection system connected to the neutron experimental stations and if necessary convert them to an unified data storage format.
- Creation and development of the information infrastructure to provide a mechanism of interaction between participants of the research process.



Reconstruction of the Laboratory Complex PIK

Cold Neutron Source for Channel HEC-3 of the reactor PIK

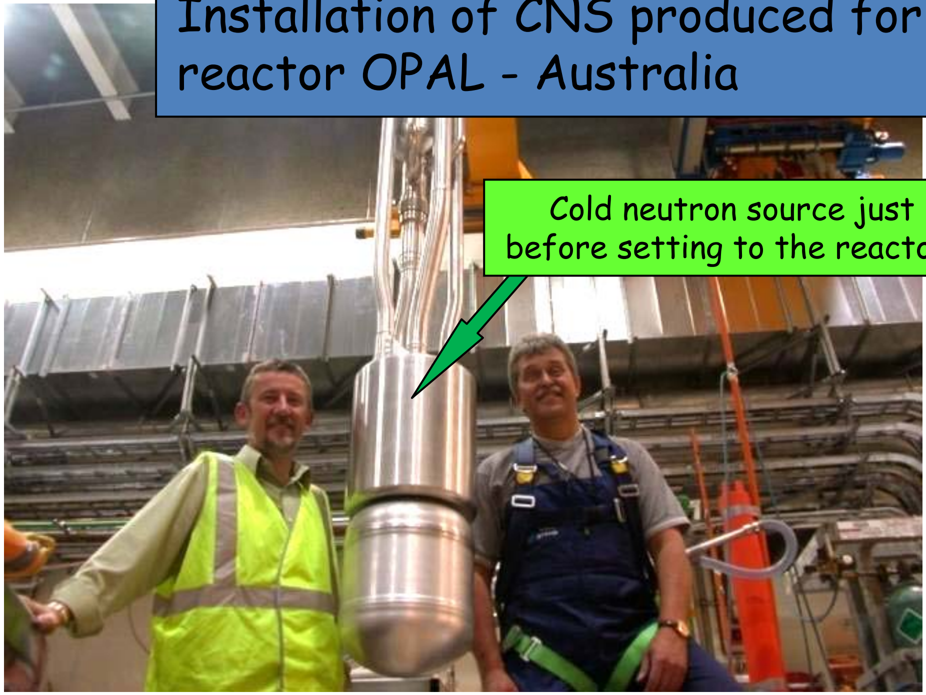
Project of CNS Channel HEC-3 of reactor PIK



(1) The reactor vessel
(2) Heavy water reflector tank
(3) Support tube for CNS
(4) Protection
(5) Steel cladding of light water pool
(6) Biological protection of the reactor
(7) Channel HEC-3
(8) Vacuumcontainer
(9) Thermosiphon

UCN source - parameters
Liquid deuterium - 25 L, **T = -250° C**
The distance from the active zone of the reactor-60cm
The flux density of cold neutrons - **6×10^{10} н см$^{-2}$с$^{-1}$,**
which is 3-5 times higher than the same values of the CNS at high-flux reactors HFR at the ILL and OPAL at ANSTO.

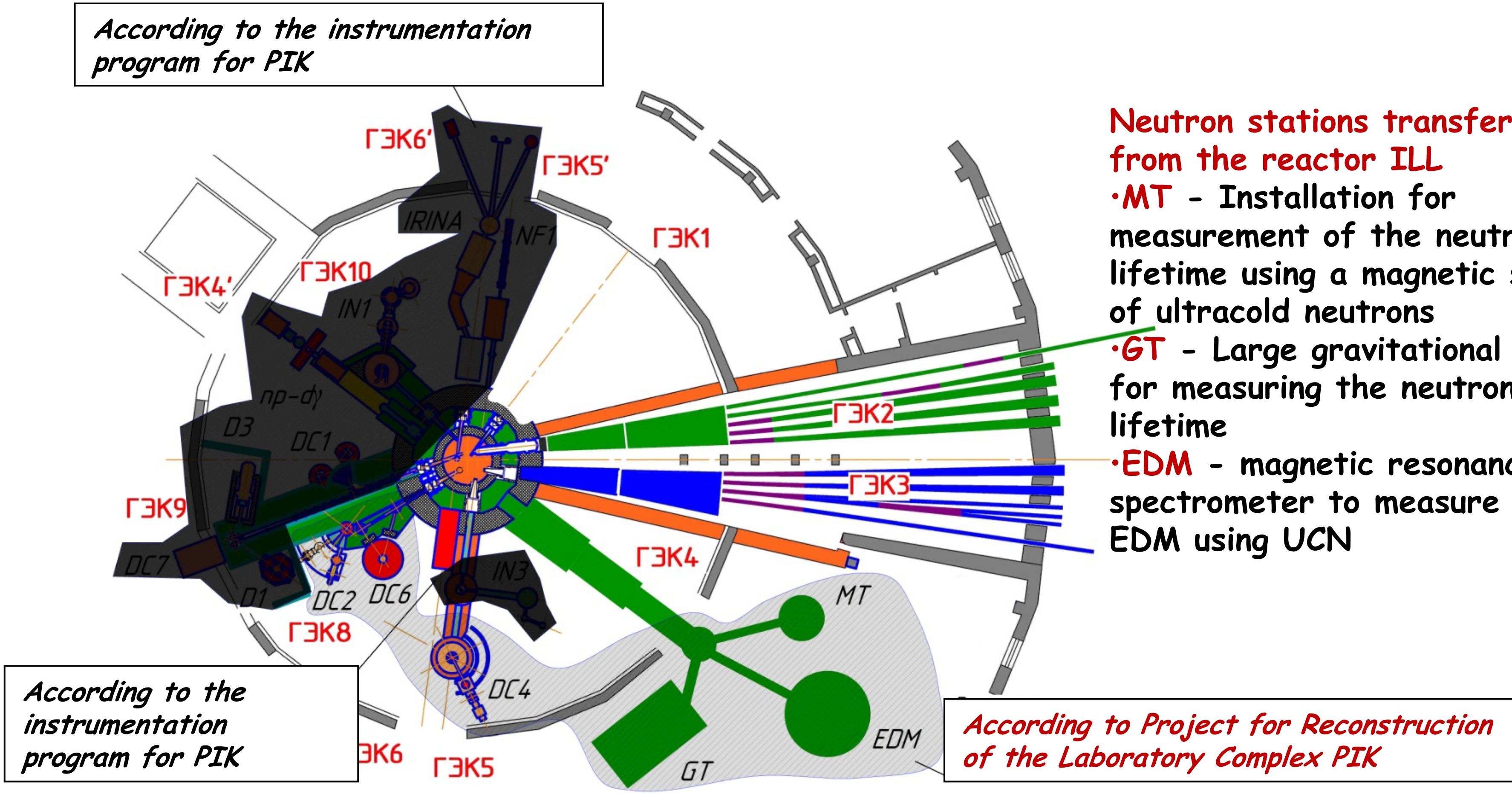
Experience of PNPI NRC KI
Installation of CNS produced for reactor OPAL - Australia



Cold neutron source just before setting to the reactor

Reconstruction of the Laboratory Complex PIK

Hall of Horizontal Channels



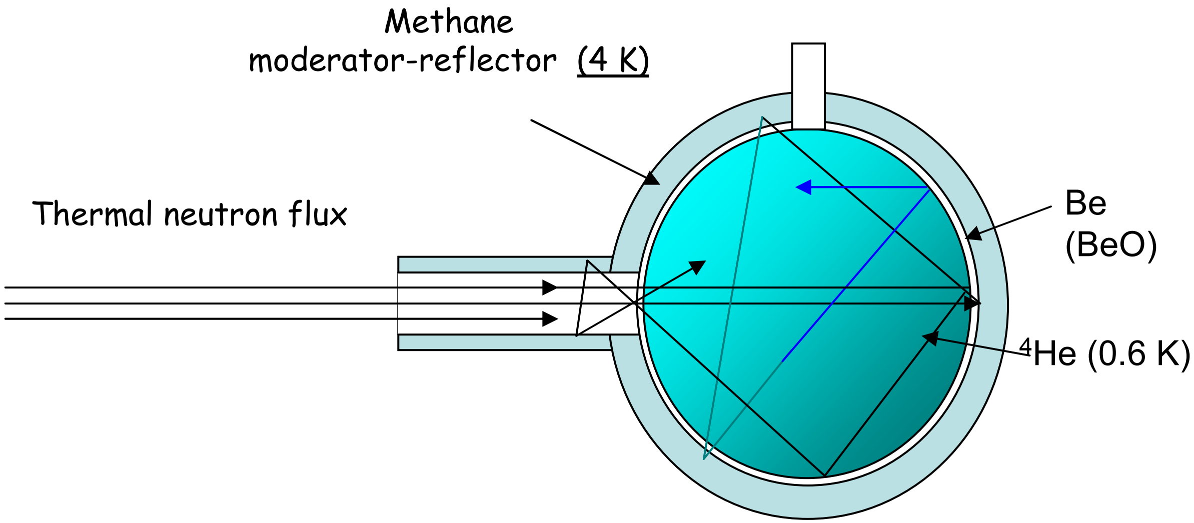
Neutron stations transferred from the reactor ILL

- MT - Installation for measurement of the neutron lifetime using a magnetic storage of ultracold neutrons
- GT - Large gravitational trap for measuring the neutron lifetime
- EDM - magnetic resonance spectrometer to measure the EDM using UCN

Neutron stations transferred to NRC KI PNPI from HZG (Geesthacht)

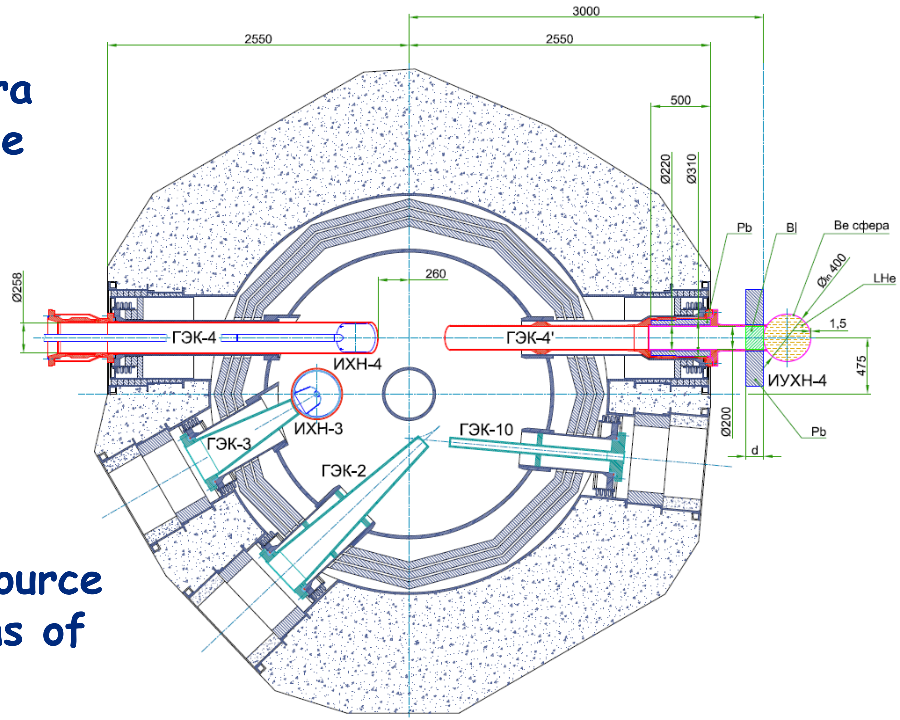
- DC4 - polarized neutron diffractometer with a two-dimensional detector POLDI
- DC6 - Texture diffractometer TEX
- DC2 - Stress diffractometer ARES

Ultra Cold Neutron Source on HEC-2



Schematic view of the idea of the helium ultra cold neutron source on thermal neutron source

E.V. Lychagin, A.Yu. Muzychka,
G.V. Nekhaev, E.I. Sharapov,
A.V. Strelkov (JINR, Dubna),
V.V. Nesvizhevsky (ILL, Grenoble)

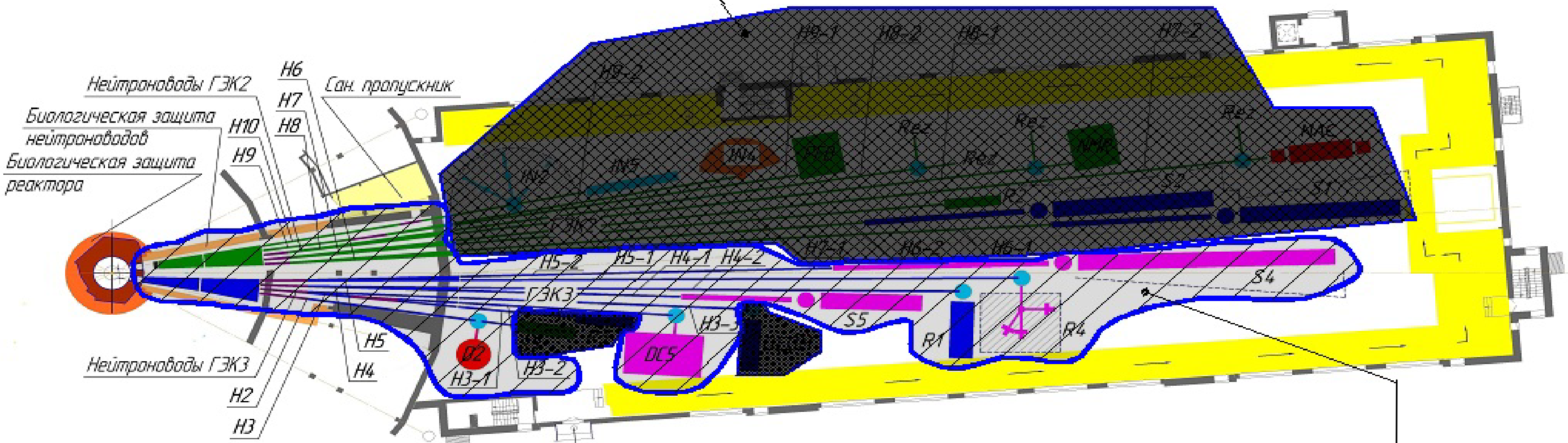


Placement option for ultra cold neutron source on extracted channel of thermal neutrons of the reactor PIK

Reconstruction of the Laboratory Complex PIK

Neutron Guide Hall

According to the instrumentation program for PIK



According to the Project for Reconstruction of the Laboratory Complex PIK

Neutron stations transferred from the WWR-M

- **D2** - powder diffractometer of cold neutrons
- **R1** - polarized neutron reflectometer with a vertical plane of reflection REVERANS

Neutron stations transferred to NRC KI PNPI from HZG Geesthacht

- **DC5** - perfect crystal diffractometer DCD
- **S-4** - small-angle scattering setup of polarized neutron SANS-2
- **S-5** - small-angle scattering setup of polarized neutrons SANS-3
- **R4** - polarized neutron reflectometer with polarization analysis NERO

Instrument status and update plans

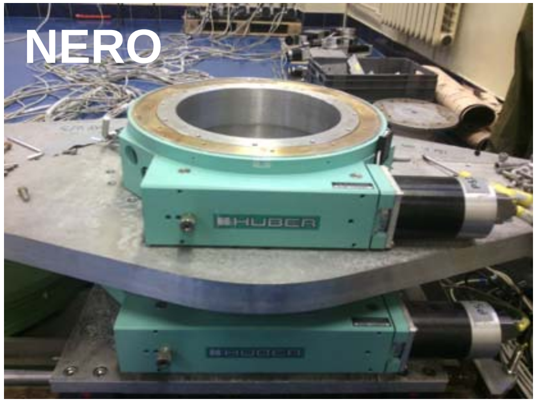
Instrument Status:

- First containers with instruments have been unpacked

- Inventory of instrument components

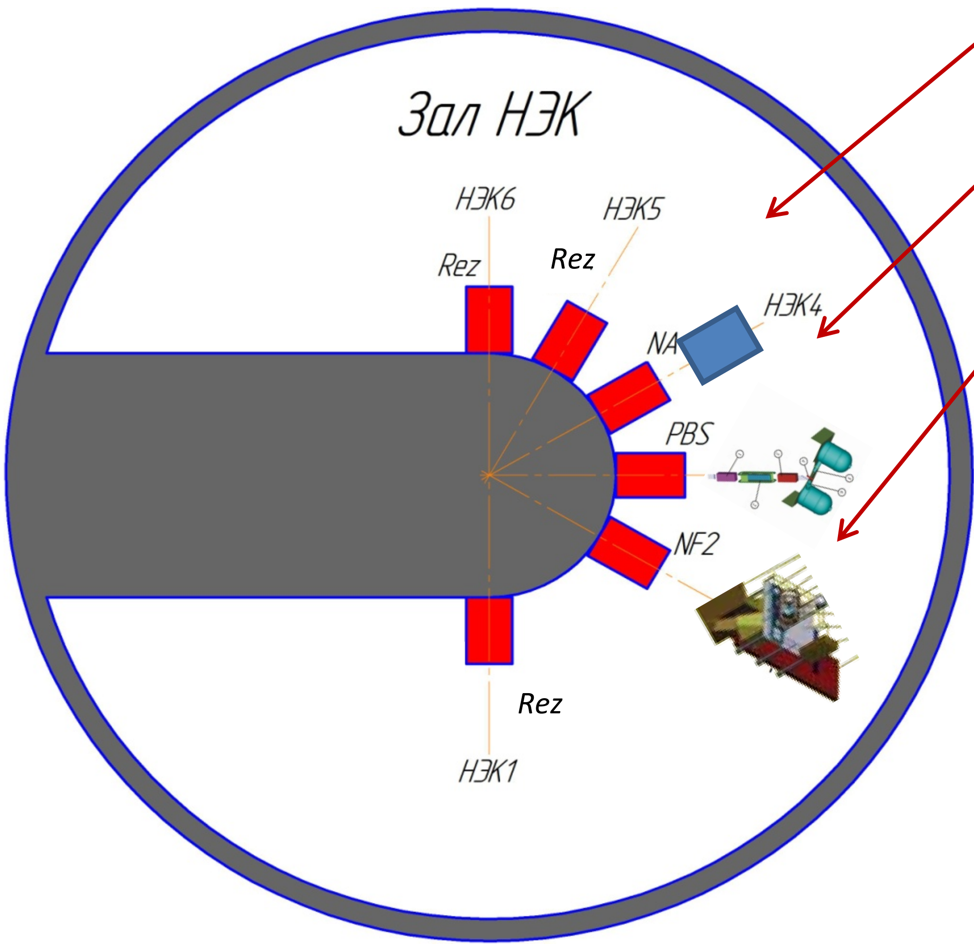
-Test of instrument components

-Reconstruction started



A. Schreyer

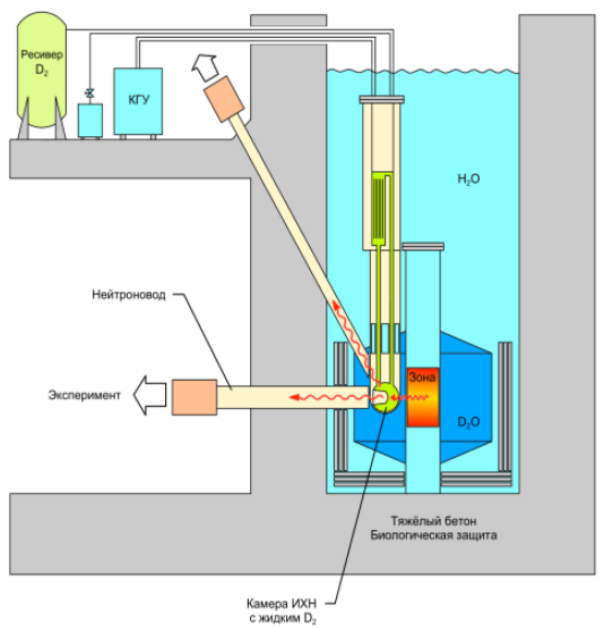
Hall of Inclined Channels (3)



NA - Neutron Activation Analysis.

PBS - Nuclear spectroscopy in the capture of thermal neutrons

NF2 - Correlation investigations in fission



The project aiming to equip RC PIK with the modern experimental stations for the multidisciplinary research will be started and completed within the period between 2015 and 2020.

The Government of the Russian Federation has approved the idea to organize the International Center for Neutron Research based on the reactor complex PIK.

NATIONAL RESEARCH CENTRE

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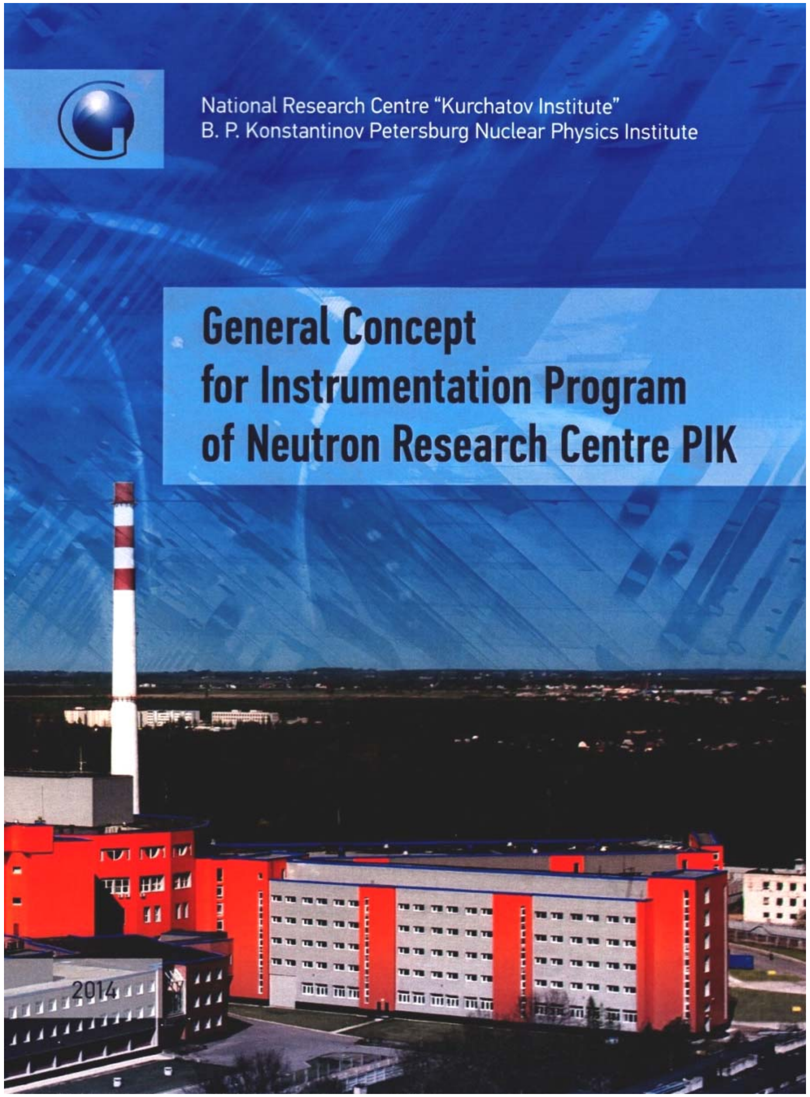

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B.P. Konstantinov Petersburg Nuclear Physics Institute

Reactor Complex PIK

Science editors: **V. L. Aksenov**, **M. V. Kovalchuk**

Volume 1 Concept of the investment project “Modernization of engineering technical systems supporting the operation of the PIK Reactor and the operation of its research stations”

Volume 2 Scientific Case Complex of experimental stations at the PIK Reactor

Volume 3 Concept of the investment project “Reconstruction of the laboratory facilities at the Reactor Complex PIK”

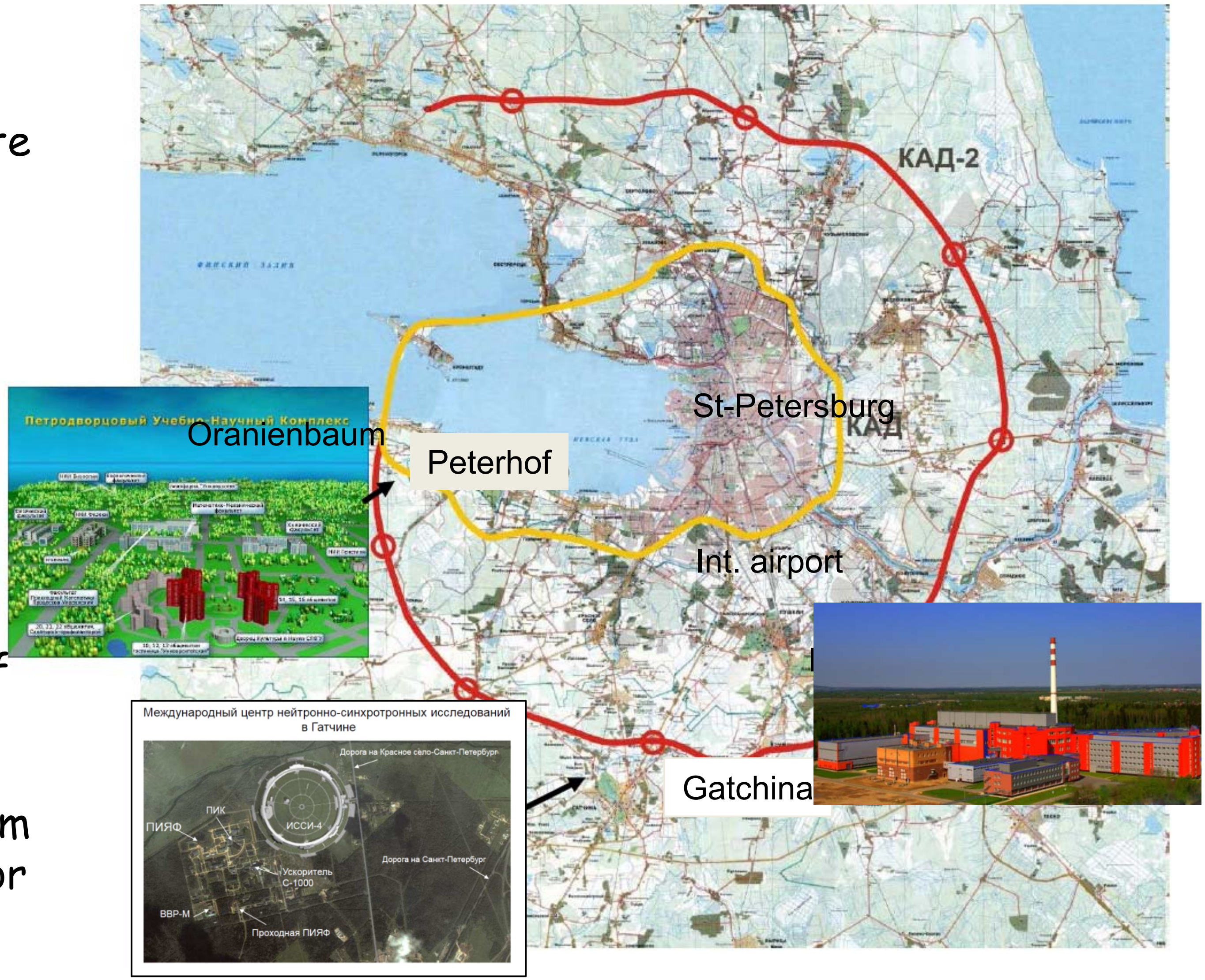
Volume 4 Concept of the investment project “Instrumentation base of the Reactor Complex PIK”

Gatchina 2014

Education:

Physics Faculty in St. Petersburg State University

The dean:
Prof. M.V. Kovalchuk



Plans: Construction of the synchrotron radiation facility in Gatchina at about 1 km away from the reactor PIK

Welcome to Gatchina