National Research Center "Kurchatov Institute"

B.P.Konstantinov Petersburg Nuclear Physics Institute

PIK reactor instrumentation program

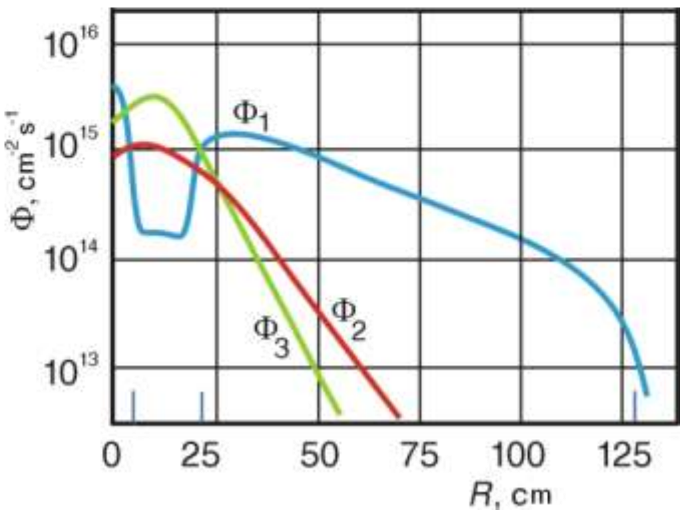
Vladimir Voronin

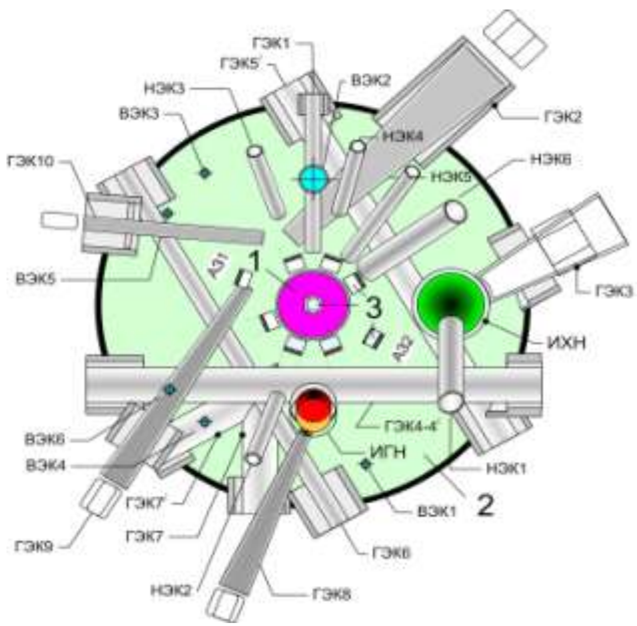
23-rd International Seminar

on Interaction of Neutrons with Nuclei

25-29 of May 2015, JINR, Dubna

PIK reactor parameters



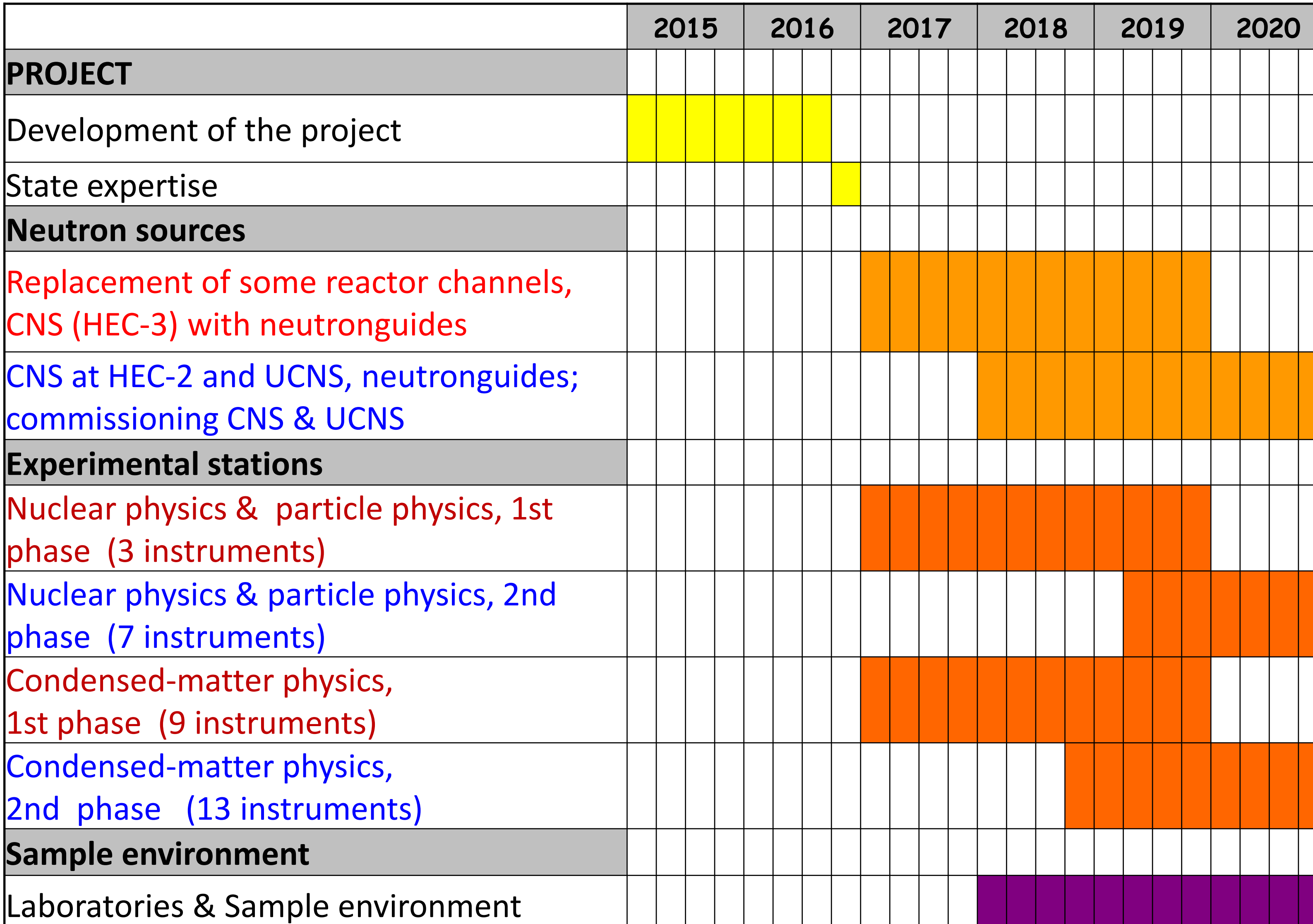


	Value
Power	100 MW
Reactor core volume	50 l
Core height	500 mm
Moderator	H_2O
Reflector	D_2O
Maximal neutron flux in moderator	1.3×10^{15} n/cm^{2}c
Maximal neutron flux in central trap	5×10^{15} n/cm^{2}c
Operation cycle	~30 day
Experimental channels	
- Horizontal (HEC)	10
- Vertical (VEC)	7
- Inclined (IEC)	6

Three step of the PIK reactor complex commissioning

1. Modernization of PIK reactor complex (2018)
2. Reconstruction of PIK laboratory complex (first phase) (2019) – one CN source and 12 experimental stations will be install (3 for NP)
3. Creation of the experimental station complex at PIK reactor (second phase) (2020) – CN and UCN sources and 20 experimental stations will be created (7 for NP)

Road map of instrumentation program



Conception of PIK instrumentation program

The 11 workgroups on various topics were organized to develop the conception of PIK reactor instrumentation program.

More than **50 scientists** from neutron center of Russia and Europe:

- PNPI NRC «Kurchatov institute»
- Joint Institute for Nuclear Research (Dubna),
- Helmholtz-Zentrum Geesthacht (Germany)
- Institut Laue-Langevin (Grenoble, France)
- European Spallation Source (Lund, Sweden).
- and other …

actively worked under this conception.

More than ten national and international workshop were organized.

РК ПИК

National Research Centre "Kurchatov Institute"
B.P. Konstantinov Petersburg Nuclear Physics Institute

Reactor complex PIK

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

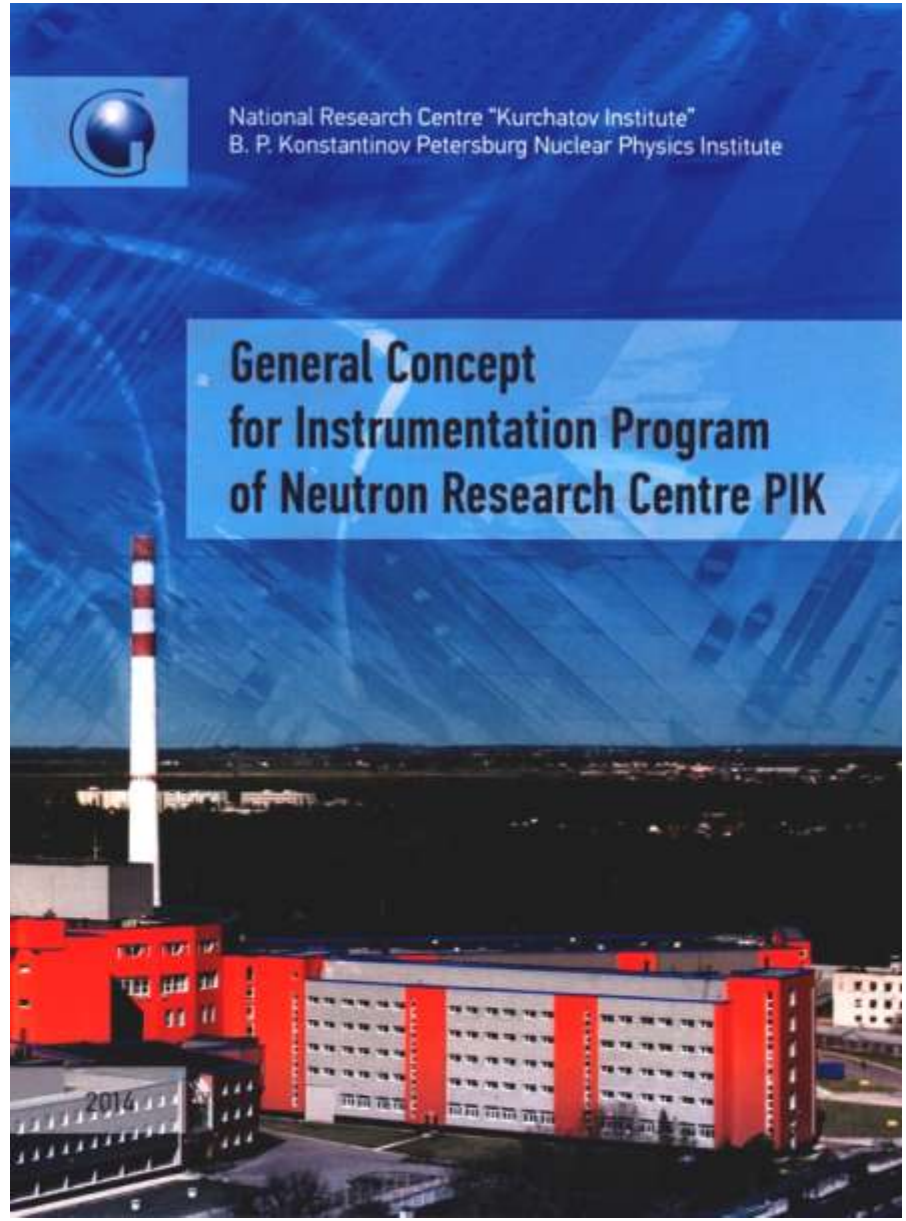
Volume 1 Concept of the investment project "Modernization of engineering technical systems supporting the operation of the PIK Reactor and the operation of its research stations"

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



Main direction of instrumentation program realization:

Infrastructure of the experiments

- Cold and ultracold neutron sources (1+2)
- Neutronguide complex
- Sample environments
- Neutron detection technology
- Computer information center

Experimental stations for condense matter physics **(22 stations)**

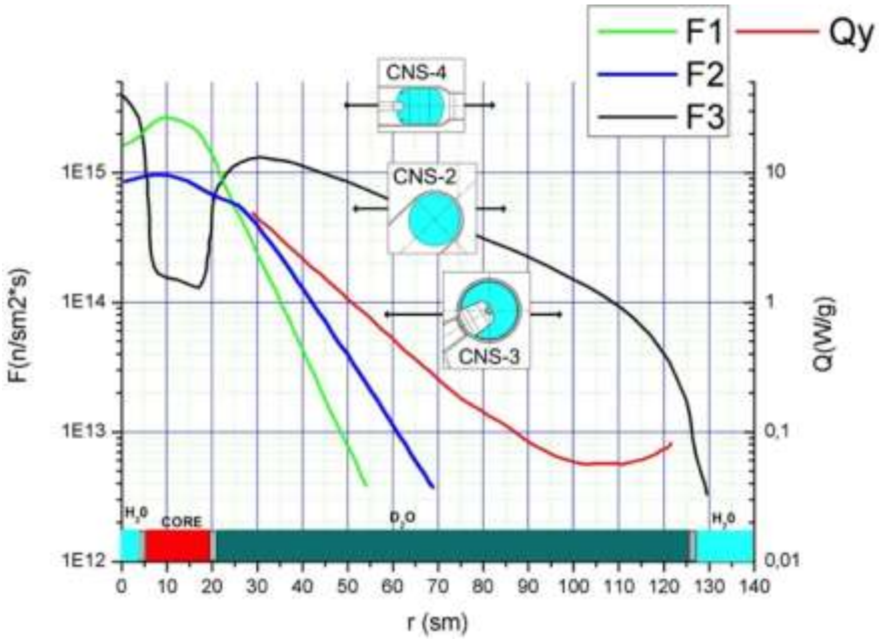
- Diffractometry complex (4+3)
- Neutron spectroscopy (0+5)
- Small angle neutron scattering (3+3)
- Reflectometry (2+2)

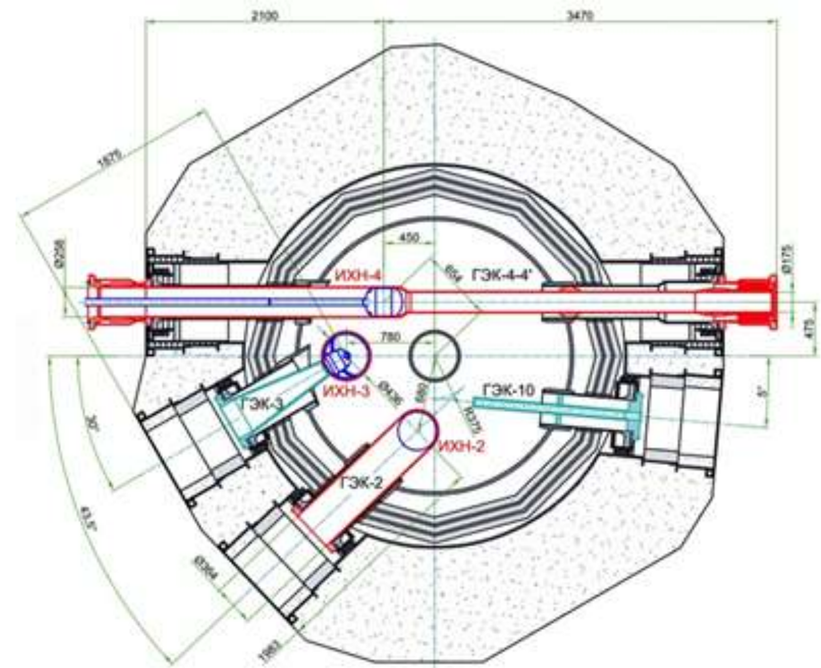
Experimental stations for nuclear and particles physics **(10 stations)**

- Ultracold neutron beam positions and experimental stations (3+0)
- Neutrino experiment (0+1)
- Cold and thermal neutron beam positions and experimental stations (0+3)
- Nuclear spectroscopy (0+3)

(first+second phase)

Cold neutron sources at PIK reactor





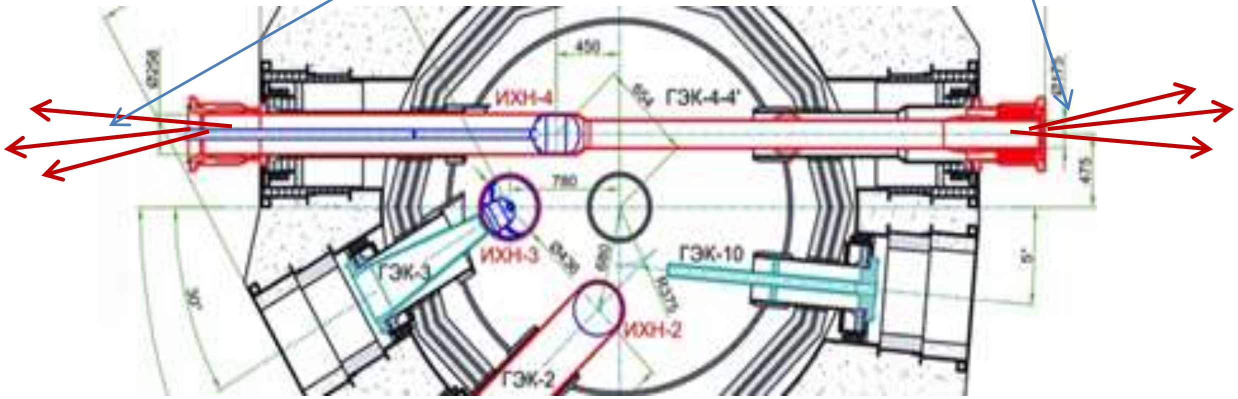
1. Cold neutron source at HEC-3 (first phase)
2. Cold neutron source at HEC-2 (second phase)
3. Cold neutron source at HEC-4-4' & UltraCNS (second phase)

The construction of these source allows to have up to 50 beam positions with neutrons of different energy at PIK reactor

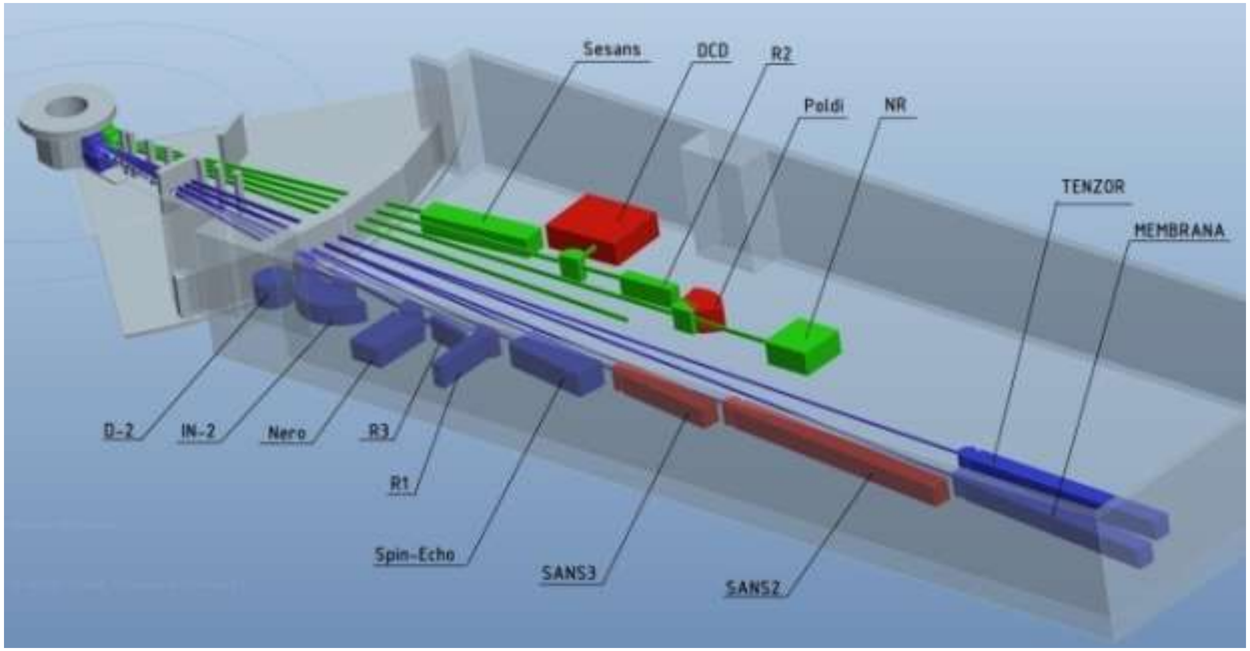
Cold neutron sources at PIK reactor

Cold neutron flux available for the users can be ~ **7 10^{10} $cm^{-2}c^{-1}$**

Parameter	ANSTO	PIK (HEC-3)	PIK (HEC-4-4')	PIK (HEC-2)	ILL (V/H)
Reactor power	20	100	100	100	57
CN flux density at the source, $cm^{-2}s^{-1}$	1.65 10^{14}	4 10^{14}	6 10^{14}	5 10^{14}	4.6 10^{14}/ 8 10^{14}
CN flux density at the exit from reactor, $cm^{-2}s^{-1}$	**(1.8-2.5) 10^{10}**	**6.0 10^{10}**	**7.6 10^{10}**	**1.7 10^{11}**	**10^{10}/ 4 10^{10}**
CN flux density at the neutronguide hall, $cm^{-2}s^{-1}$	**6.4 10^{9}**	**~10^{10}**	**>10^{10}**	**>10^{10}**	**6 10^{9}**



Reactor PIK neutronguide system



Whole length of neutroguides
1240 meters (10 channel)

Surface square (m=2 - 4) 600 m^2

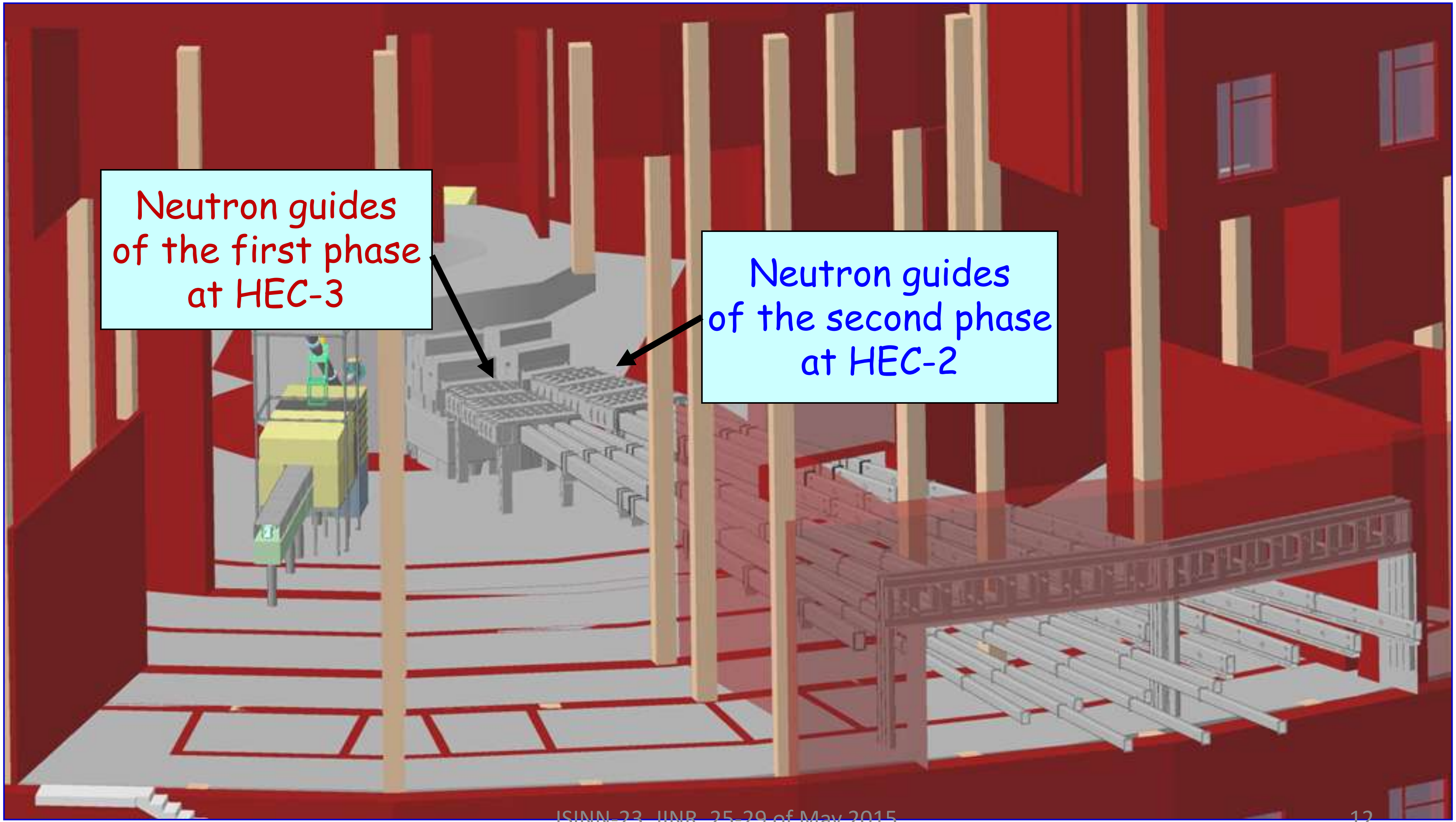
Neutronguide system is the system of optical channel for neutron beam splitting, transportation and focusing. Main conception – optimization for the purpose of experimental station.

Two phases of the system creation

1-st phase is the neutronguide system of HEC-3 (5 channel)

2-nd phase is the neutronguide system of HEC-2 (5 channel)

Front view of the neutron guide system of the reactor PIK

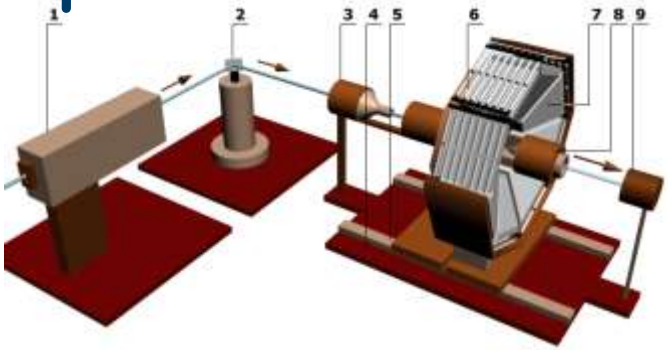


INTERNATIONAL COOPERATION

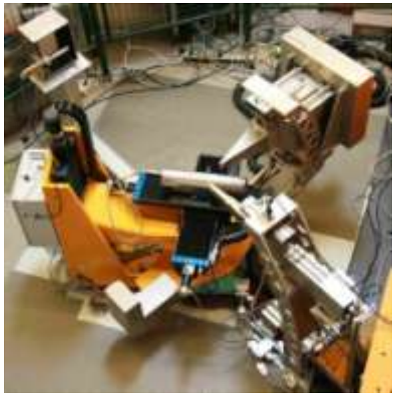
7 neutron stations (with the total cost of 30 mln. euro) were transferred from the Helmholtz Center Geesthacht (Germany) to the Petersburg Nuclear Physics Institute of NRC "Kurchatov Institute".

The instrument SANS2 has reached its destination. PNPI employees are placing the equipment at the neutron guide hall of reactor PIK.

Diffractometry complex



1. **High resolution powder diffractometer of thermal neutrons** dedicated for the determination of atomic and magnetic structures in compounds, mostly inorganic, in polycrystalline form and with low unit cell dimensions;
2. **High resolution powder diffractometer of cold neutrons** with ability to resolve crystalline and magnetic structures in molecular crystals with large number of atoms in the unit cell, commensurate and incommensurate superstructures with long periods, etc;



3. **High flux diffractometer of thermal neutrons** for investigations of the atomic scale arrangement in micro-samples, and samples under extreme conditions, as well as of amorphous and liquid states;
4. **Four circle diffractometer of thermal neutrons** dedicated for detailed studies of complex magnetic and atomic structures in single crystals;
5. **Polarized neutron single crystal diffractometer with 2D detector** (in cooperation with HZ Geesthacht, Germany) probing e.g. spin density distributions;
6. **Texture diffractometer** (in cooperation with HZ Geesthacht, Germany);
7. **Residual stress diffractometer** (in cooperation with HZ Geesthacht, Germany).

Neutron spectroscopy for inelastic scattering

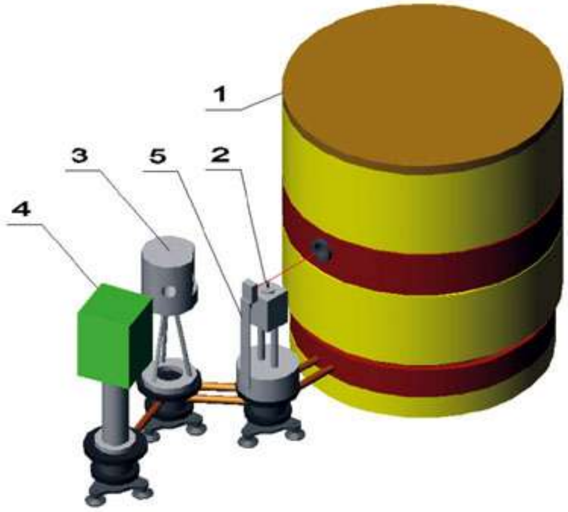
1. **The triple axis spectrometer of thermal neutrons** probing high energy branches of collective excitations spectrum in single crystals;

2. **The triple axis spectrometer with full polarization analysis** optimized for investigations of magnetic excitations in single crystals;

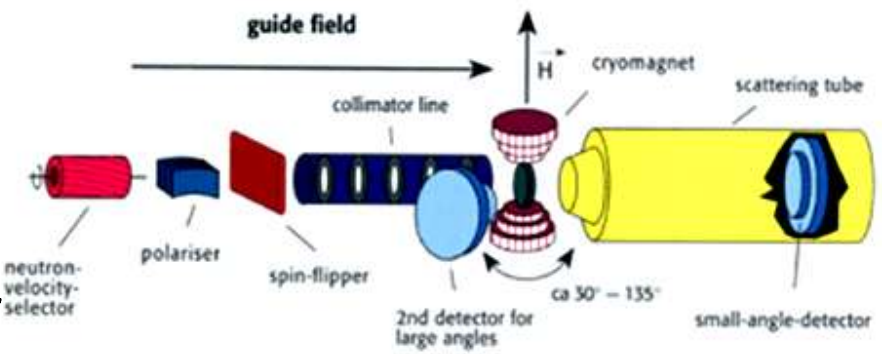
3. **The triple axis spectrometer of cold neutrons** probing low energy excitations in single crystals;

4. **The multifunctional Time-of-Flight (TOF) spectrometer** utilizing a broad band of incoming neutron energies is dedicated for detailed studies of atomic and molecular dynamics in solids and liquids;

5. **The Spin-Echo spectrometer** providing access to e.g. relaxation dynamics in soft matter over the time scale $10^{-12} – 10^{-8}$ s.



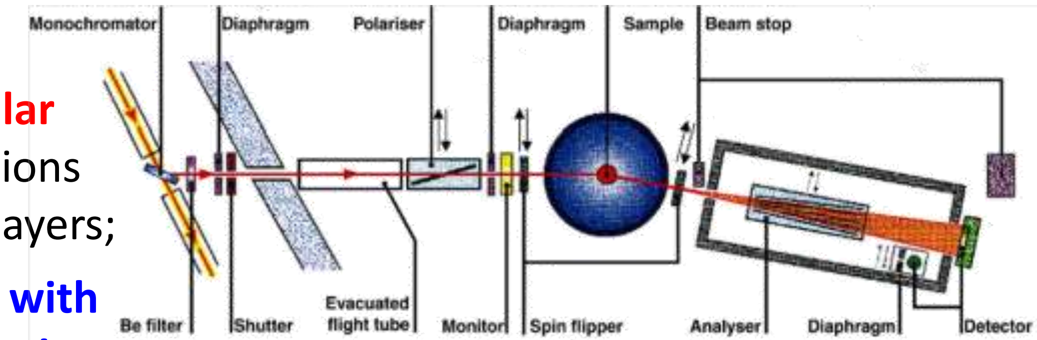
Small angle neutron diffractometers



1. **The High resolution SANS diffractometer of polarized neutrons** for fundamental and applied research in the field of nano-magnetism and electrodynamics of superconductors;
2. **The High intensity SANS diffractometer** mostly dedicated for soft matter and biological problems, as well as to probe of small samples;
3. **The SANS machine** with extended range of wave vector transfer achieved with e.g. TOF option and the use of a high resolution position sensitive detector in the near forward direction along with bands of multidetectors recording larger scattering angles. Diffractometer is dedicated for investigations over exceptionally large range of scales required to the determination of multiscale structures, such as components of biological cells;
4. **The SANS apparatus** with an equipped pair of position sensitive detectors can simultaneous record two complementary scales of the wave vector transfer;
5. **The Ultra Small Angle Neutron Scattering (USANS) Double Crystal Diffractometer (DCD)** accessing physical information at exceptionally small wave vector transfer;
6. **The Spin-Echo SANS (SE-SANS)** facility probing extra-large structures up to a submillimeter scale in direct space. This facility may be applied to study e.g. Biological agglomerates and substances with dimensions comparable to live cells.

Reflectometries

1. **The high resolution reflectometer with the horizontal plane of specular reflection** (vertical orientation of reflecting surface) specialized for investigations of solid state thin films and multilayers e.g. with lateral microstructures. The machine operates in the angular dispersive mode with a constant, but variable wave length of incident neutrons, providing an extended range of the wave vector transfer;
2. **The high luminosity reflectometer with the horizontal plane of specular reflection** specialized for investigations of ultrathin, e.g. mono-molecular, layers;

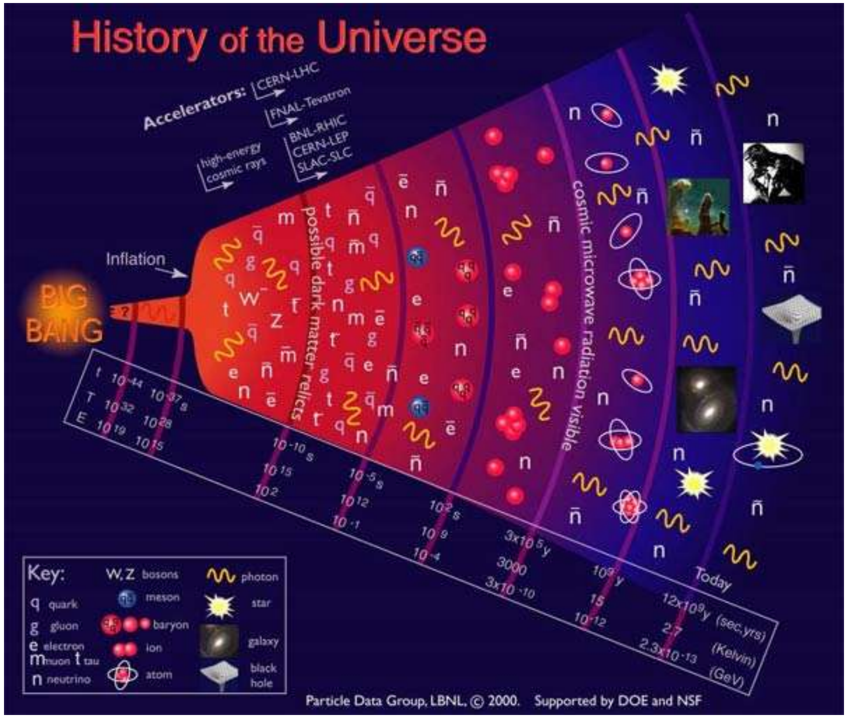


3. **The high luminosity reflectometer with the vertical plane of specular reflection** (horizontal surface) probing liquid surfaces and interfaces, e.g. in native biological membranes, electrolytes, etc. This machine is supposed to operate in either the angular dispersive, or TOF mode.
4. **The reflectometer for neutron optics** operating in the angular and the wave length varied (TOF) modes.

Experimental stations for nuclear and particles physics

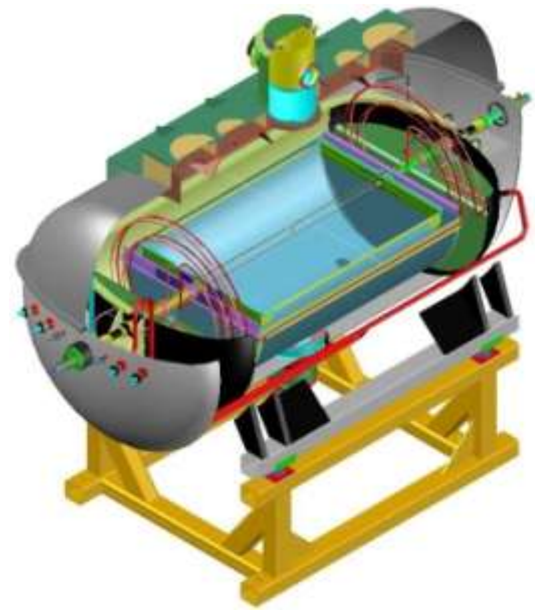
The main direction

- Ultracold beam positions and experimental stations
- neutrino experiment
- Experimental stations at cold and thermal neutron beam
- Nuclear spectroscopy



Reports of A.P Serebrov, V.N.Panteleev and D. Nesterenko

Physics with UCN and neutrino

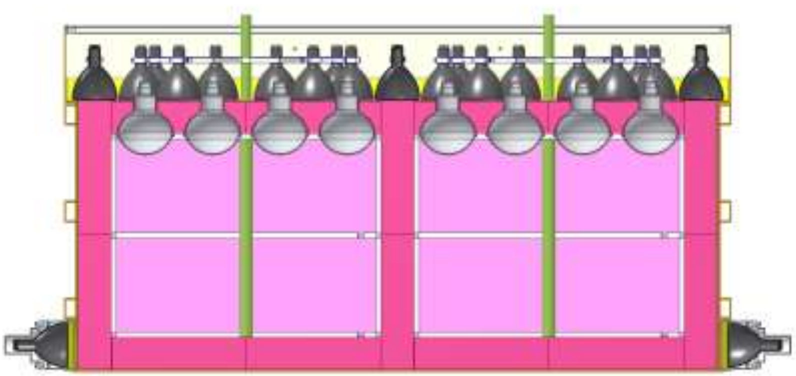


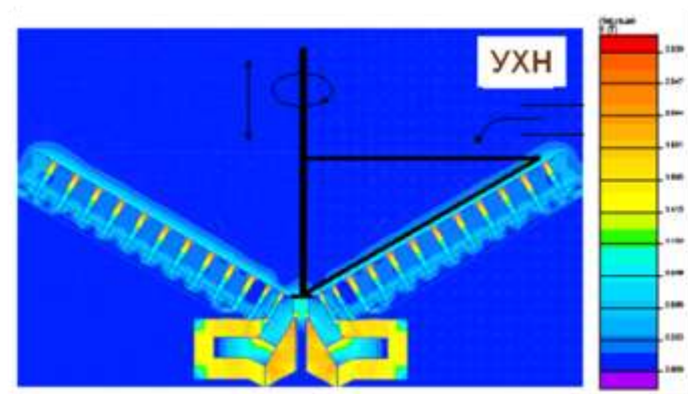
Recommendations is to equip three UCN beam positions for the experiments of first-priority

1. **Neutron EDM search.**
   Goal is to get the **best world accuracy – up to 10^{-28} e cm.**
2. **Neutron life time experiments**
   1. In large material trap
      Goal if to get accuracy ~**0.2 s.**
   2. Magnetic trap with well control of neutron loss.

4. Sterile neutrino experiment.

Goal is to study the **neutrino oscillation at (5-15)m with best world accuracy and solve the problem of deficit of reactor neutrino**





Cold and thermal neutron beam positions for particle physics

1. Beam position with cold neutron. (NG hall)

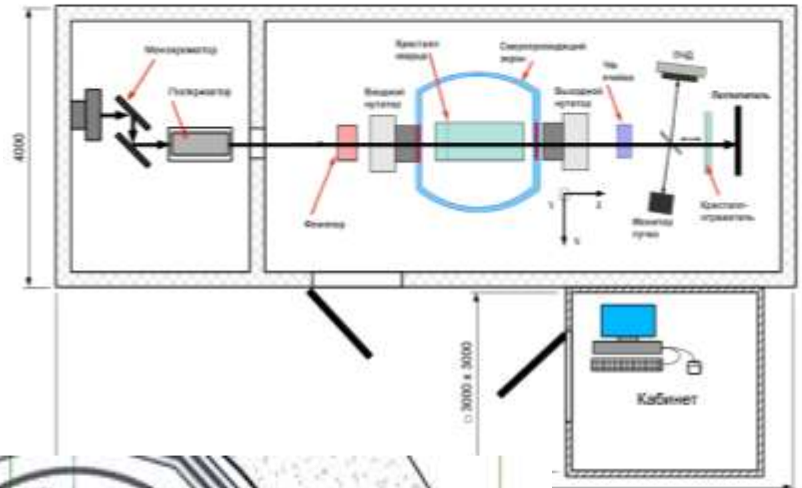
Goal is to equip the beam position for the wide range experiments in nuclear physics and physics of elementary particles and to install the setup (Crystal-diffraction neutron EDM experiment).

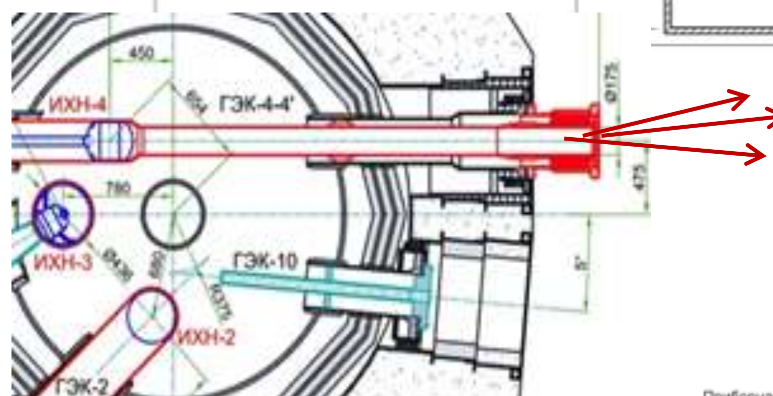
2. Polarized cold neutron beam position (hall of HEC)

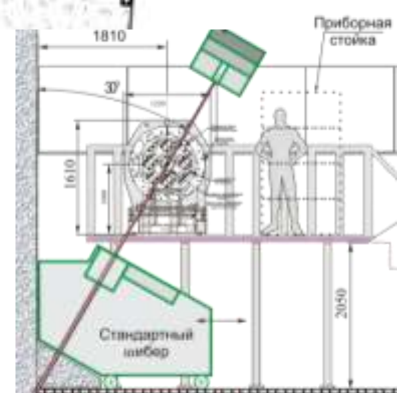
Goal is to equip the beam **position with the world record flux of polarized cold neutrons** and install the setup for neutron decay asymmetry measurement with accuracy $\mathbf{10^{-3}}$

3. Thermal neutron beam position for nuclear fission physics (hall of IEC) and install the setup for fission fragments study.

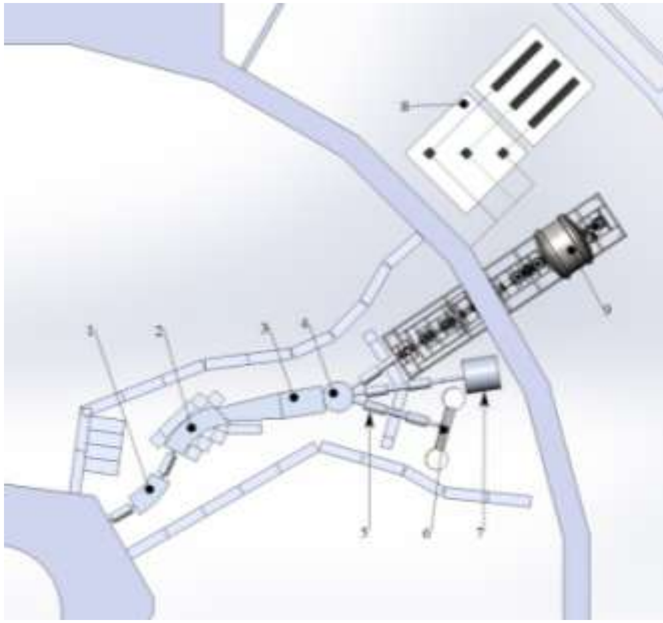
(poster of V.E. Sokolov)







Nuclear spectroscopy



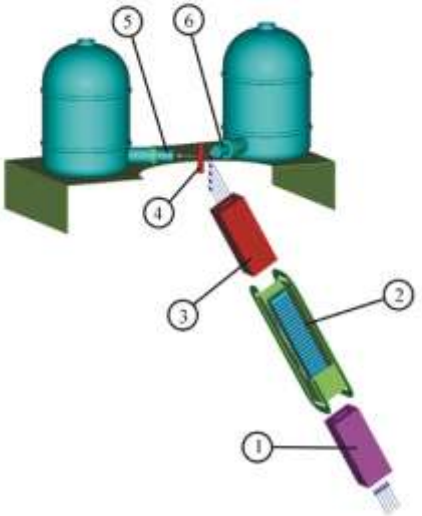
1. Mass separator laser-nuclear complex IRINA. (hall of HEC) (ISOL+ISOLTRAP)

Goal is to study of the properties of nuclei with a large number of neutrons, the study shape the nuclei near the boundary of neutron stability.

Precision measurements of masses of nuclei far from the condition of beta-stability.

Production of high purity radioisotopes for nuclear medicine.

(Reports of V.N. Panteleev and D. Nesterenko)



2. Nuclear radiation spectrometer . (hall of IEC)

Goal is the measurement of emissions from neutron capture reaction cores for the study of nuclear structure.

3. Neutron activation analysis. (hall of IEC)

INAA - Instrumental Neutron Activation Analysis.

NRA - Neutron Radiation Analysis

Experiments on the central channel of PIK reactor

Thermal neutron flux in central trap **5×10^{15} n/cm^{2}c**

High neutron flux in the central channel of the PIK reactor allows the production of rare isotopes, whose synthesis requires two-stage process.

Target production for the synthesis of super-heavy elements

Unique possibilities for production isotopes ^{254}Es and ^{257}Fm

The production of rare isotopes for nuclear medicine

Increase the yield of isotope tungsten ^{188}W, which is used in the ^{188}Re generators.

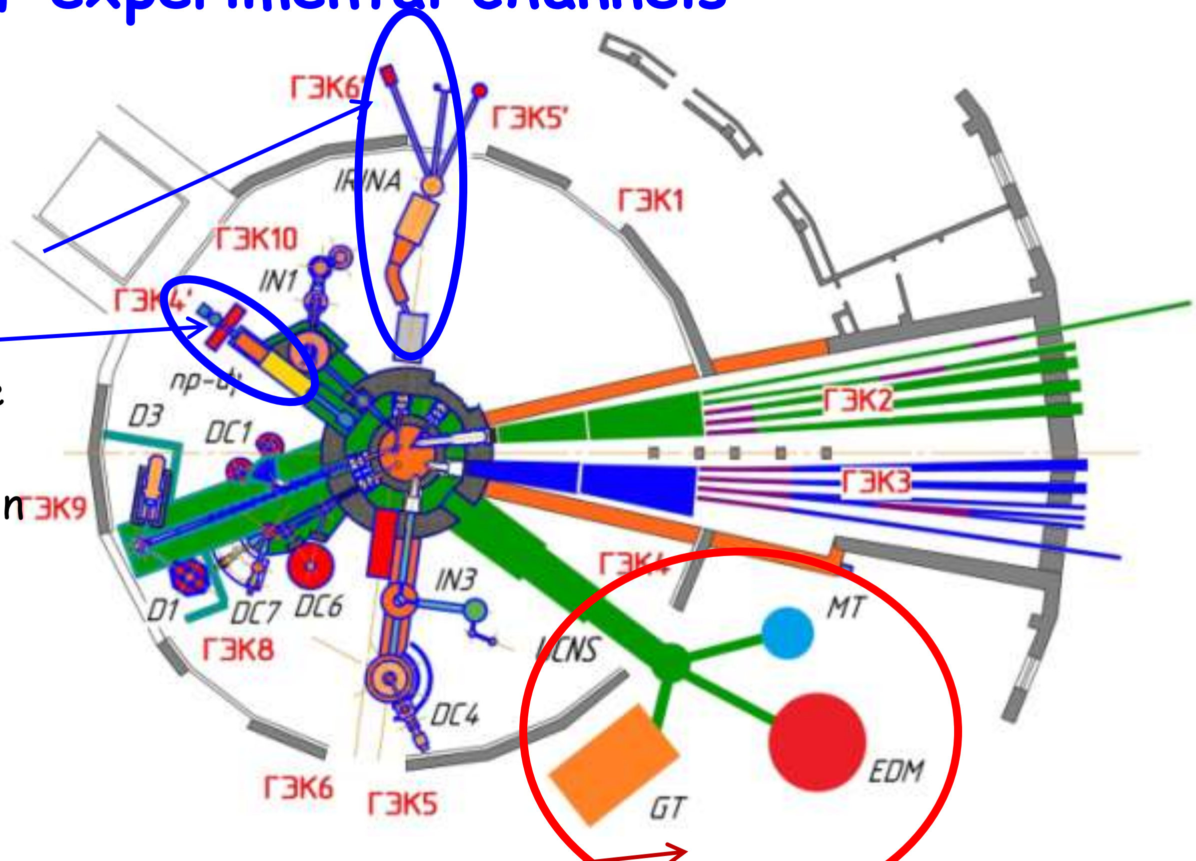
Setups for nuclear and particle physics

Hall of experimental channels

IRINA - Mass separator laser-nuclear complex

Neutron decay – Polarized cold neutron beam facility with the record cold neutron flux

n4 – «Neutrino» facility (located in the under-reactor space)

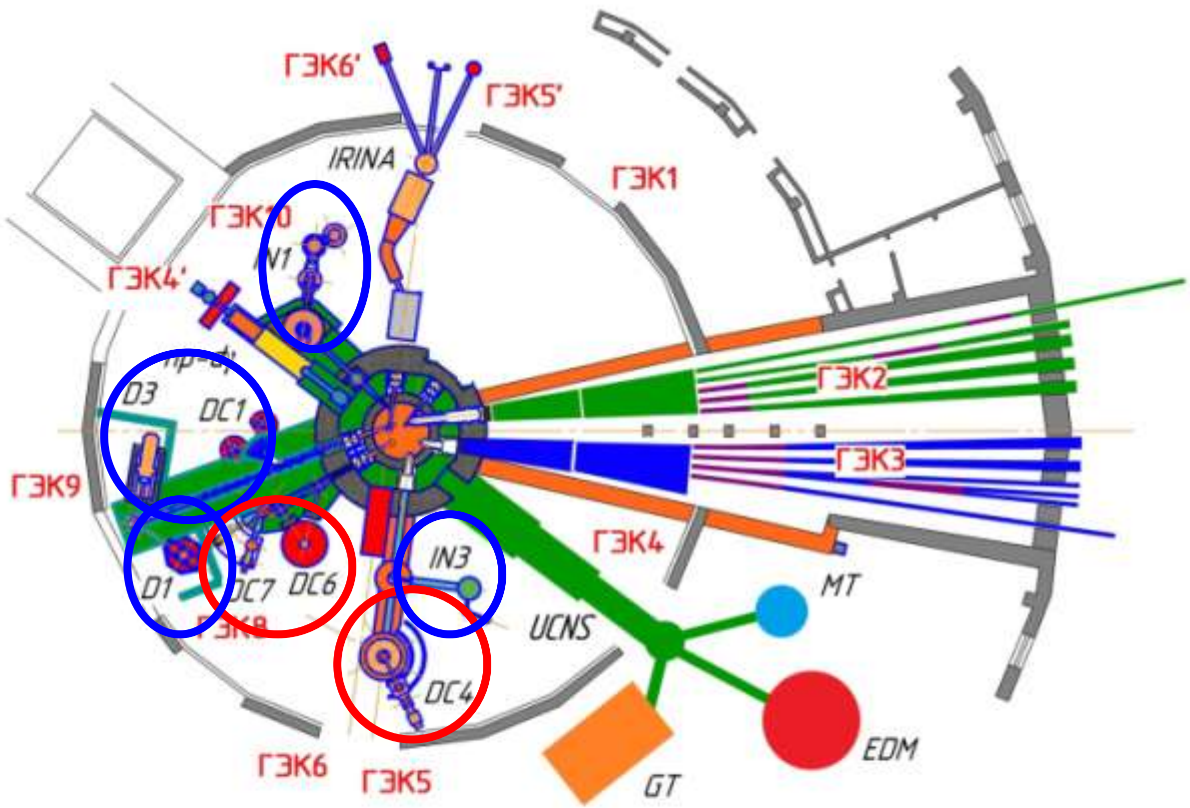


- **MT** - Installation for measurement of the neutron lifetime using a magnetic storage of ultracold neutrons
- **GT** - Large gravitational trap for measuring the neutron lifetime
- **EDM** - magnetic resonance spectrometer to measure the EDM using UCN

Setups for condensed matter physics

Hall of experimental channels

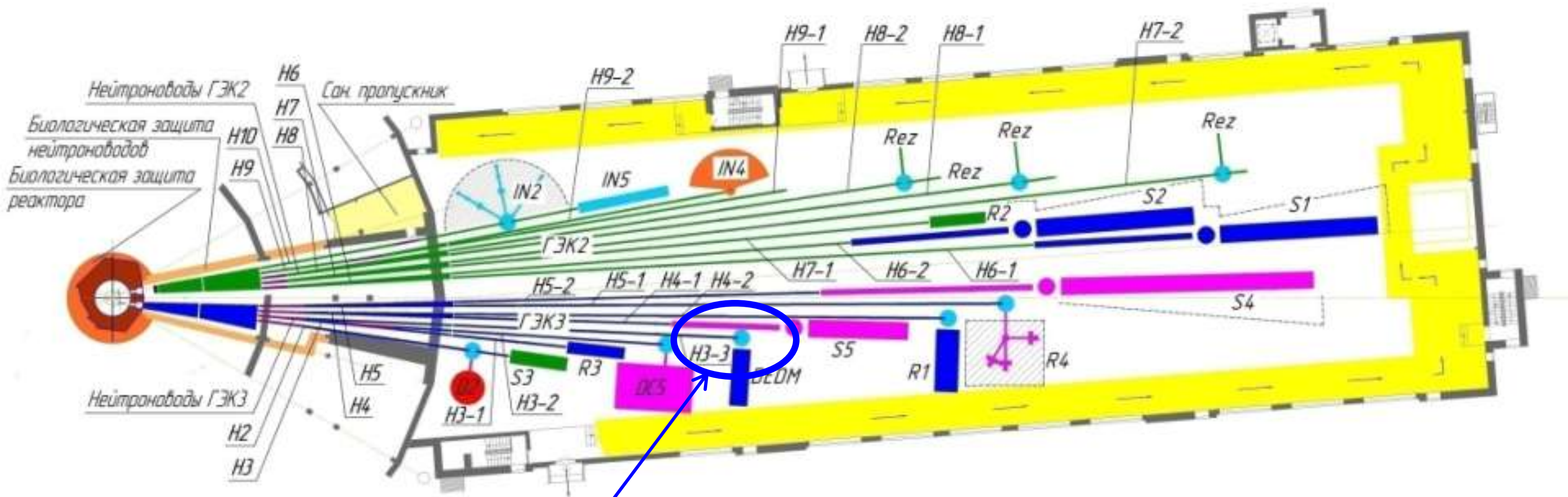
D1 - high resolution powder diffractometer of thermal neutrons
D3 - high flux diffractometer of thermal neutrons
DC1 - four circle diffractometer
IN1 - triple axis spectrometer of thermal neutrons
IN3 - triple axis spectrometer with full polarization analysis



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

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

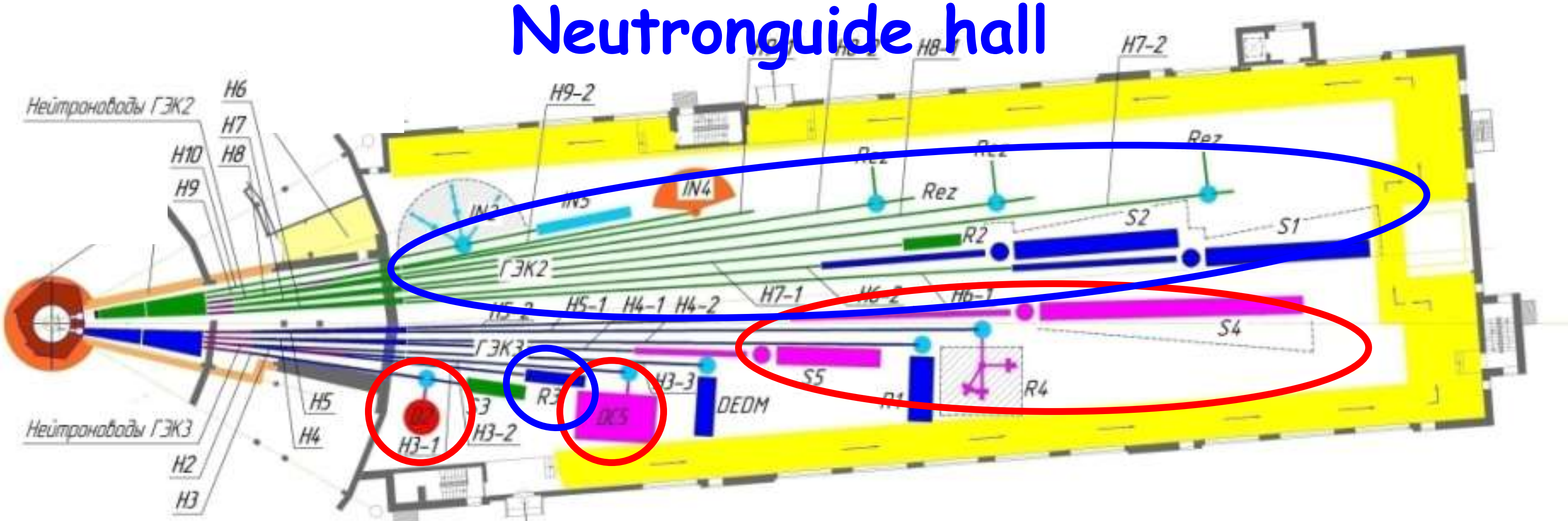
Setups for nuclear and particle physics Neutronguide hall



Position on cold neutron beam for nuclear and particle physics

Setups for condensed matter physics

Neutronguide hall



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 PNPI RNC KI 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

IN2 - triple axis spectrometer of cold neutrons

IN4 - multifunctional Time-of-Flight (TOF) spectrometer

IN5 - Spin-Echo spectrometer

S1 - high resolution SANS diffractometer of polarized neutrons

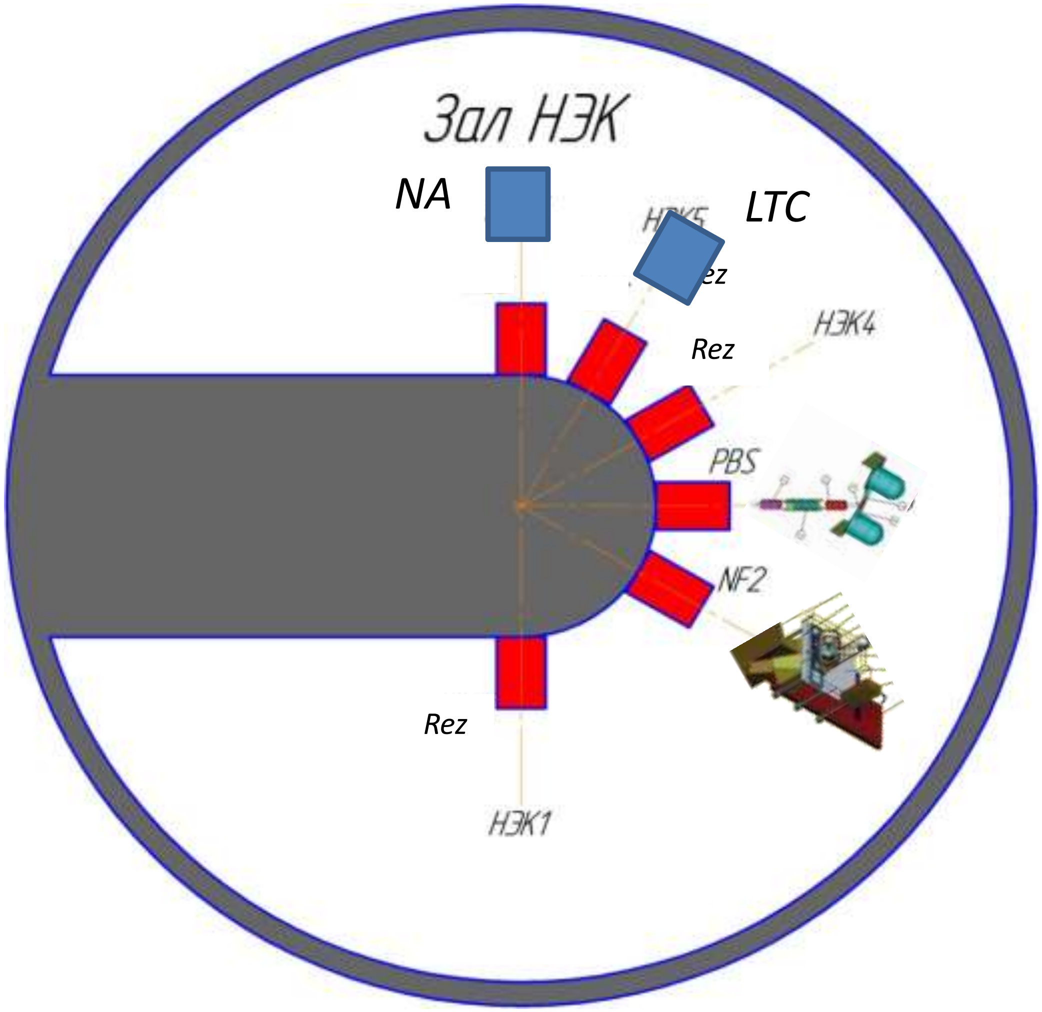
S2 - SANS apparatus

S3 - Spin-Echo SANS (SE-SANS) facility

R2 - reflectometer for neutron optics

R3 - reflectometer with 3D polarization analysis

Hall of Inclined Channels



Nuclear physics

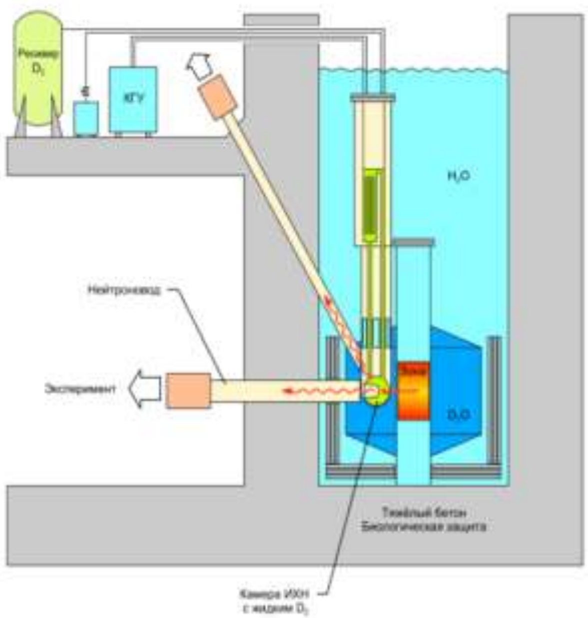
NF2 - Correlation investigations in fission

PBS - Nuclear spectroscopy in the capture of thermal neutrons

NA - Neutron Activation Analysis.

Condensed matter

LTC – low-temperature He loop for study irradiated material



Next step of the international cooperation started

Framework Cooperation Agreement between Forschungszentrum Jülich and NRC „Kurchatov Institute" has been signed on 16 June 2014

FRAMEWORK COOPERATION AGREEMENT

between

Forschungszentrum Jülich GmbH
52425 Jülich
Federal Republic of Germany
- hereinafter referred to as „*Forschungszentrum Jülich*" -

and

National Research Centre "Kurchatov Institute"

For National Research Center "Kurchatov Institute"

Prof. Dr. M. V. Kovalchuk
Director of the National Research Centre "Kurchatov Institute"
Date:

Prof. Dr. V. L. Aksenov
Director of the B.P. Konstantinov Petersburg Nuclear Physics Institute NRC "Kurchatov Institute"

For Forschungszentrum Jülich GmbH

Prof. Dr. S. M. Schmidt
Member of the Board of Directors of the Forschungszentrum Jülich GmbH

Prof. Dr. Th. Brückel
Director of the Jülich Centre for Neutron Science

The cooperation includes

- development of neutron delivery systems for the reactor PIK;
- modern methods of neutron detection, neutron polarization and neutron polarization analysis;
- development of new and advanced neutron scattering instrumentation.

The parties intend to create advisory committee and scientific subcommitties to discuss in greater detail the scientific program to be developed for the PIK reactor to establish a world-class suite.

1st Meeting of the Neutron Scientific Advisory Committee

March, 9-11 2015

CONCLUSIONS

The International Research Policy Advisory Committee of the Kurtchatov Institute has **established the NSAC – the Neutron Scientific Advisory Committee** – to give advice for the further development of neutron science in Russia in relation to the Europe Neutron Strategy. **The ultimate aim is to develop the PIK Reactor in Gatchina to be a world-class center for neutron science.** The very open and fruitful 1st NSAC meeting discussed the Russian plans for the exploitation of the new research reactor PIK in Gatchina. We thank all people involved for their excellent work preparing for the meeting and the presentations which were informative and clear at the same time.

The committee recommends the establishing of 7 sub committees*1 to further explore the fields of:

1. Diffraction
2. Spectroscopy
3. Large scale structures
4. Fundamental physics
5. Neutron optics & moderator
6. Detectors and monitors
7. Computing and data analysis

**1However, each sub-committee should be balanced in respect to Russian and non-Russian members as well as to its gender ratio.*

1st Meeting of the Neutron Scientific Advisory Committee

March, 9-11 2015

Current view on the PIK instrumentation program

Research neutron facility with unique opportunities will be created.

It will be equipped with

- Sources of cold and ultracold neutrons
- Systems of the neutronguide and neutroguide hall
- Sample environment systems
- Computing center
- **22 experimental station for condensed matter physics** and molecular biology
- **10 beam positions and experimental stations** for particle and nuclear physics

This concept is a step towards to the creation of a world-class neutron facility on the base of the RK PIC and its transformation into the **International Center for Neutron Research.**

Thank you for your attention