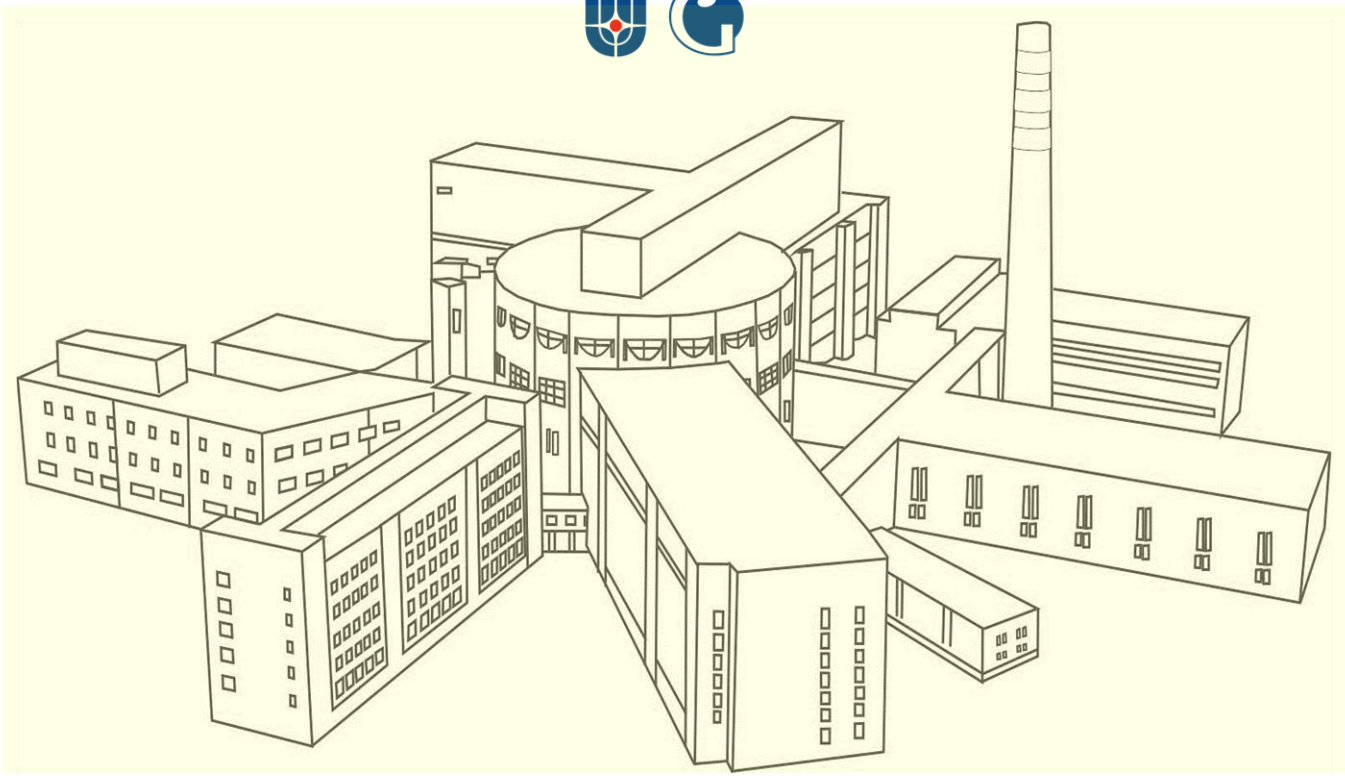
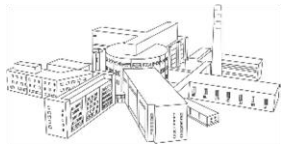
Sino-Russia meeting on frontiers of neutron scattering
(SRNS-2024)
October 8–11, 2024, Ekaterinburg

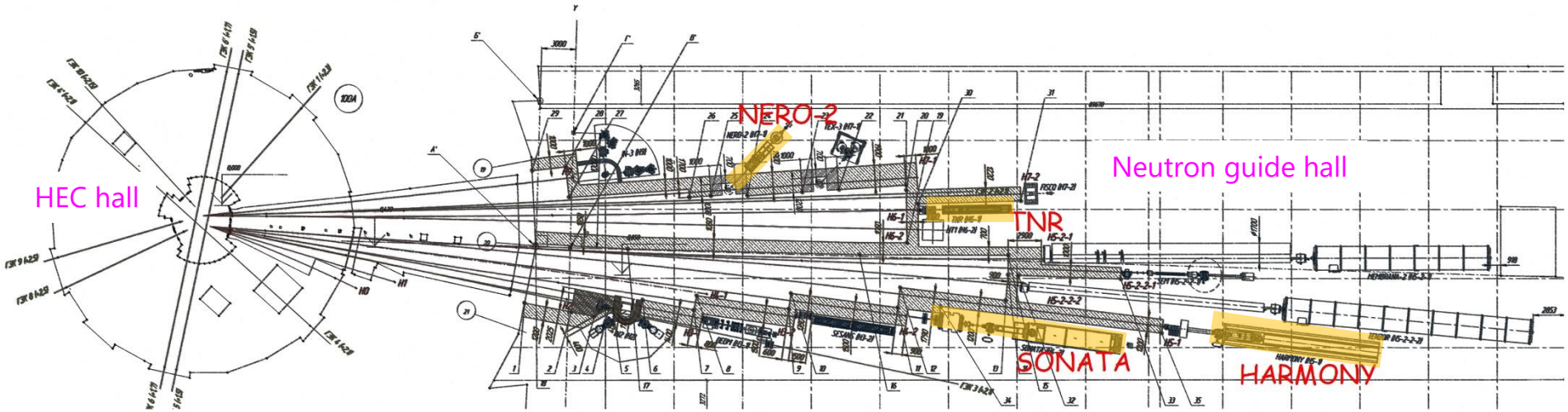
Prospects of neutron reflectometry at the reactor PIK

N.K. Pleshanov
(PNPI NRC KI - Gatchina, Russia)





Location of the reflectometers at the research reactor PIK

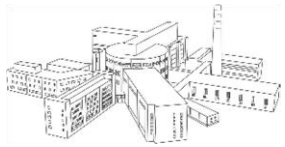


NERO-2 – high-resolution neutron reflectometer

TNR – test neutron reflectometer

SONATA – high-flux neutron reflectometer

HARMONY – liquid neutron reflectometer



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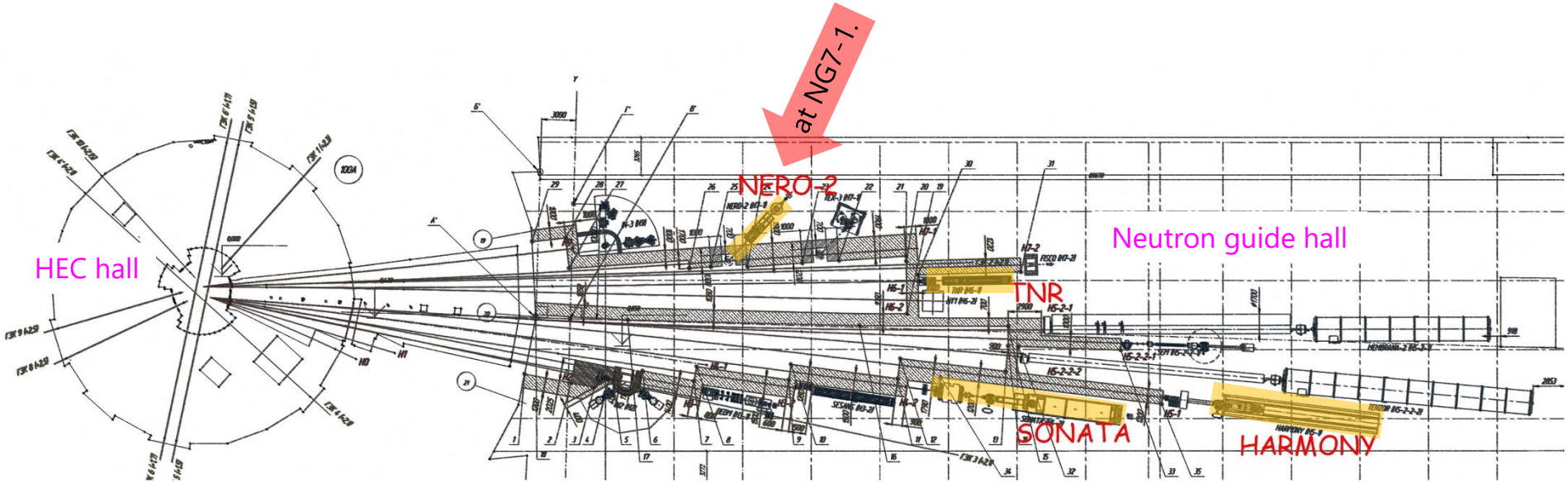

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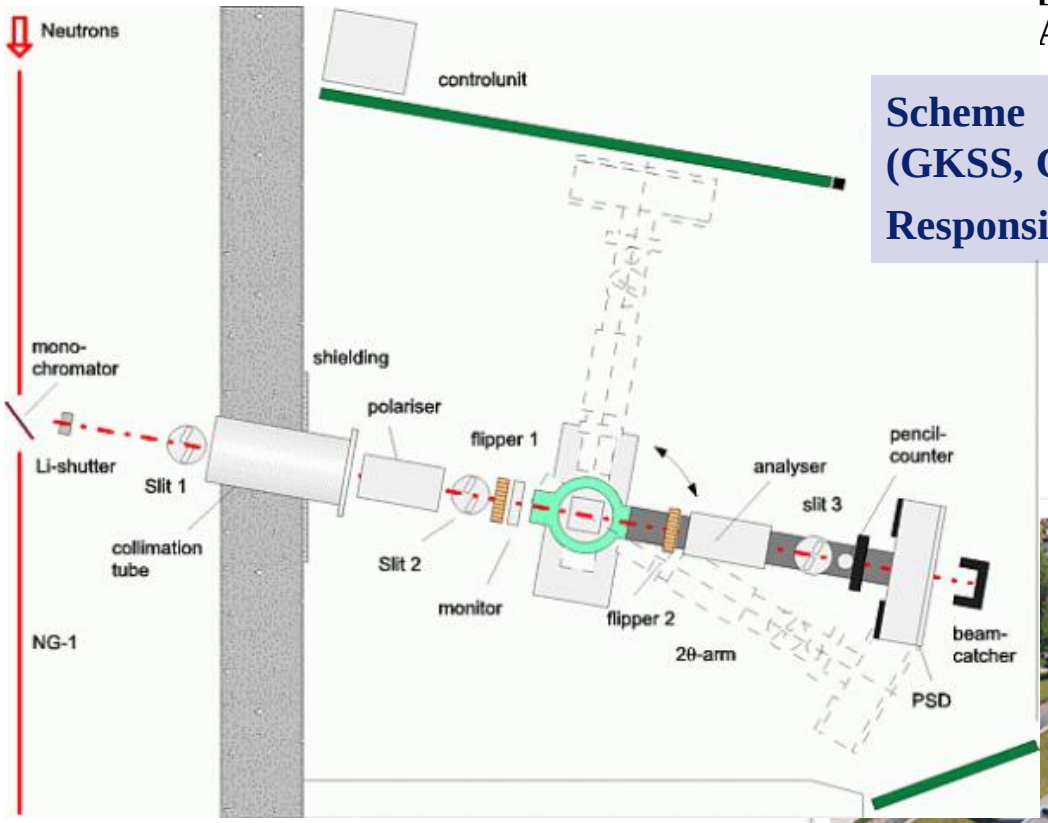
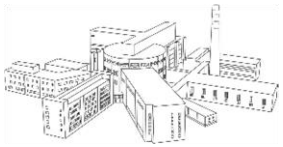
Neutron reflectometer NERO

[D. Solina, D. Lott, U. Tietze, O. Frank, V. Leiner, A. Schreyer, Physica B 385-386 (2006) 1167]

Scheme of the reflectometer NERO (GKSS, Geesthacht, Germany)

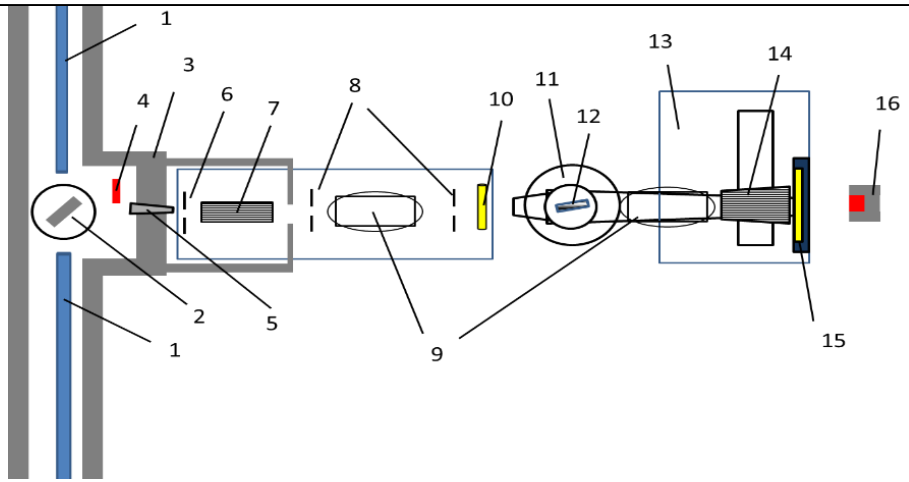
Responsibles: Dieter Lott, Danica Solina





High-resolution neutron reflectometer NERO-2

Location:
Neutron guide H7-1



1 – neutron guide; **2 – focusing monochromator**; 3 – monochromator shielding; 4 – shutter; 5 – collimator; 6 – slit; **7 – beam former**; **8 – collimation 2D-diaphragms**; **9 – flippers**; 10 – monitor; **11 – sample unit**; 12 – sample; 13 – detector platform; **14 – fan analyzer**; **15 – PSD**; 16 – beam stop

CONCEPT

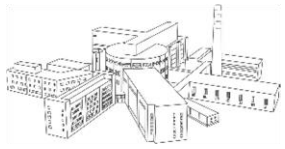
- provision of measuring in constant wavelength mode by using the crystal (HOPG) monochromator;

- provision of measuring with non-polarized and polarized neutrons, high and medium resolution, by using the beam former unit;

- provision of polarization analysis over a wide range of angles by using the fan analyzer;

- provision of the option of measurements at large diffraction angles (GID);

- measurement regimes >> geometry: slit/quasi-point; technique: constant wavelength, grazing incidence diffraction (GID); beam: non-polarized/polarized.



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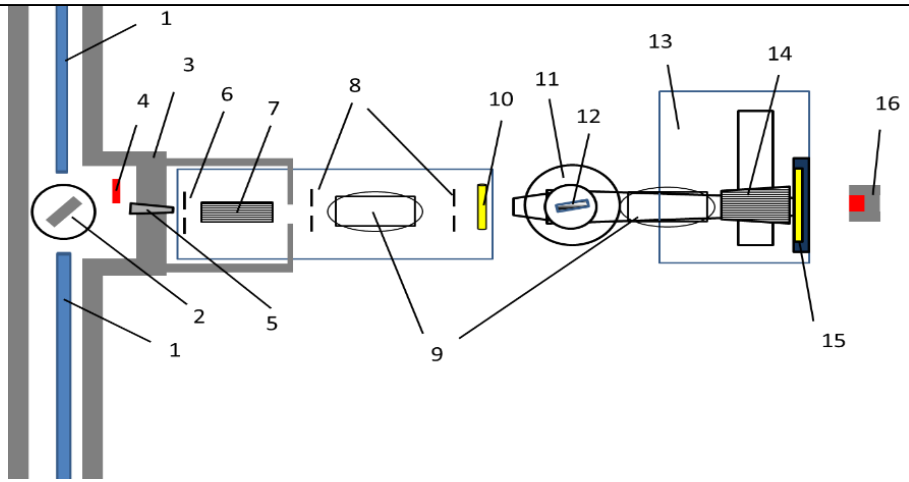

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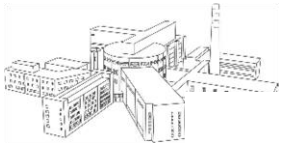
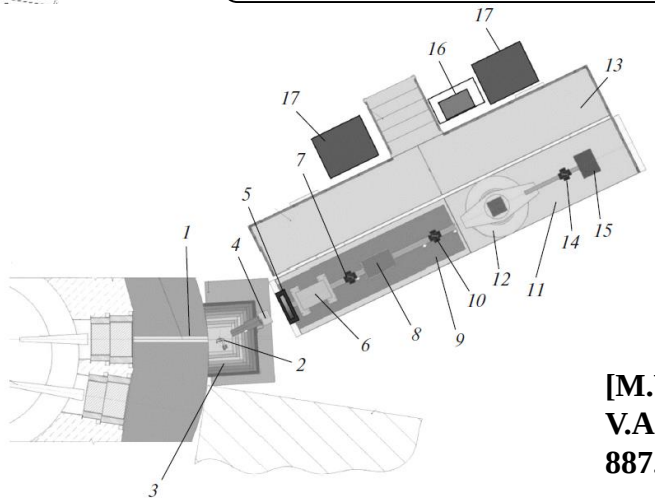
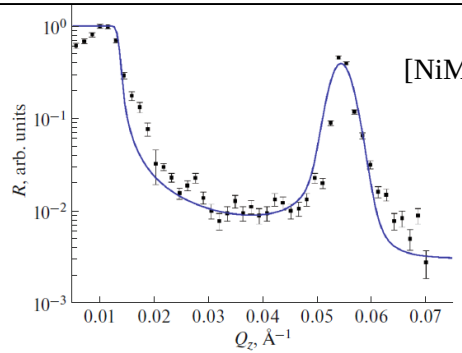
Specifications	Application
• sample: vertical • measuring technique: λ=const, GID • wavelength: λ = 0.52 (0.25) nm • neutron polarization: P > 95 % • Q_z-range: 0.01 ÷ 10 nm^{-1} • ΔQ\Q ~ 2÷3 % (1), 5÷7% (2) • detector: 250x250 mm^2 • Φ_{inc}~$4 \cdot 10^5$, 10^5 (polarized) n/s/cm^2	High-resolution studies of the structure and magnetism of thin films and multilayer nanosystems. Study of structural and magnetic correlations, influence of inhomogeneities and other imperfections on physical properties of nanostructures and on processes in layers and at layer interfaces.



High-resolution neutron reflectometer NERO-2



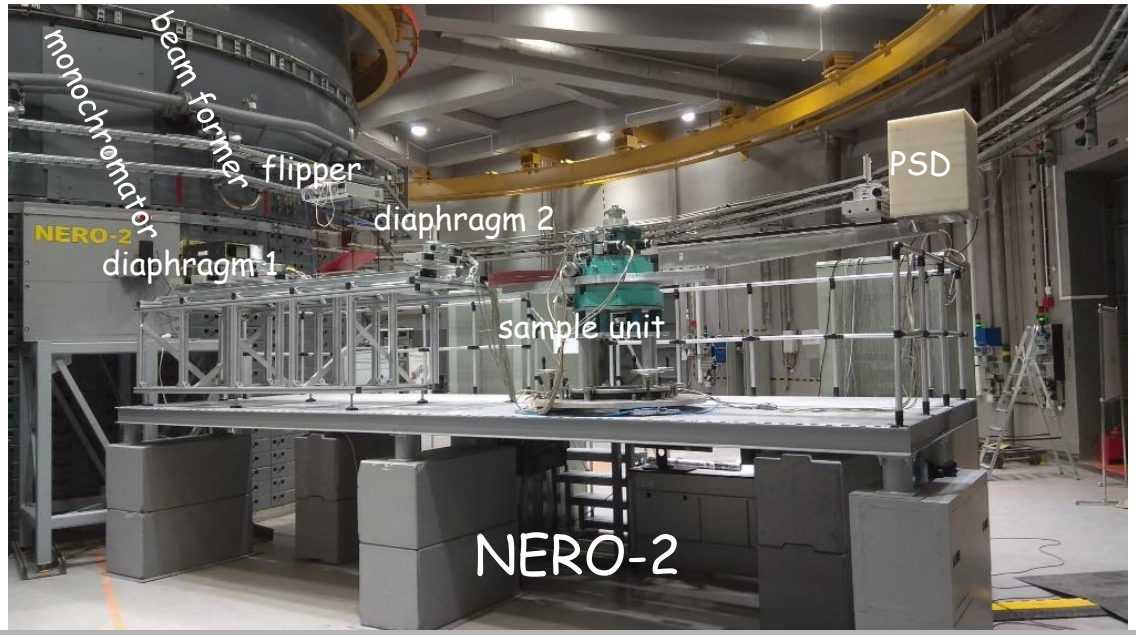


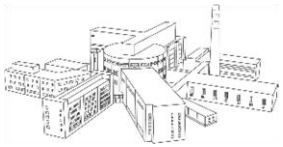
[NiMo(60Å)/Ti(60Å)]x60

[M.V. Dyachkov, V.A. Matveev, V.G. Syromyatnikov, V.V. Tarnavich, V.A. Ulyanov, J. Surf. Invest.: X-ray, Synchr. Neutron Techn. 18 (2024) 887. - First Measurements at Neutron Reflectometers TNR and NERO-2]

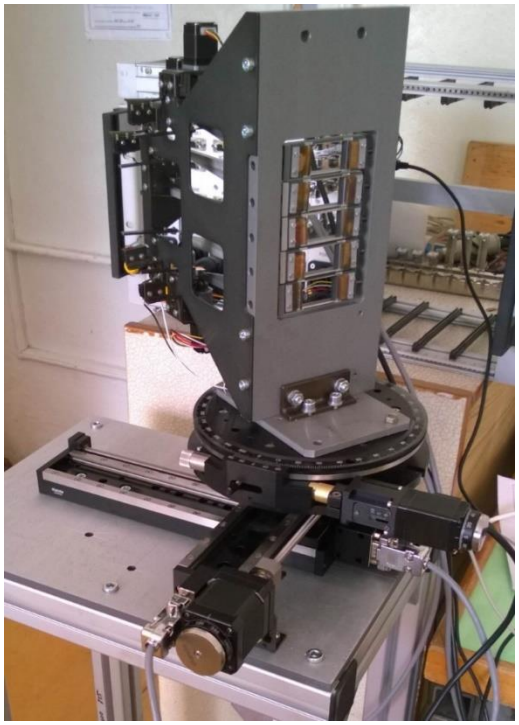
1 - collimator; 2 - focusing monochromator; 3 - shielding; 4 - beam shutter; 5 - collimation diaphragm; 6 - beam shaper; 7,10 - 2D-diaphragms; 8 - flipper; 9 - support frame; 11 - slipway; 12 - sample unit; 13 - personnel slipway; 14 - detector diaphragm; 15 - detector; 16 - control computer; 17 - electronics racks

Photo: temporary assembly at channel 8 in the HEC hall to check its functionality

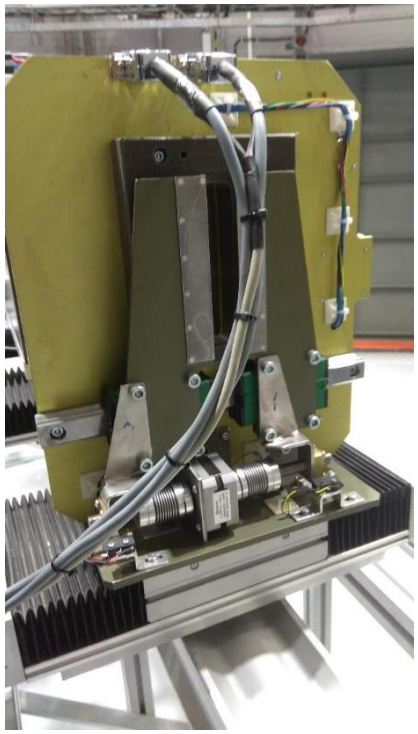




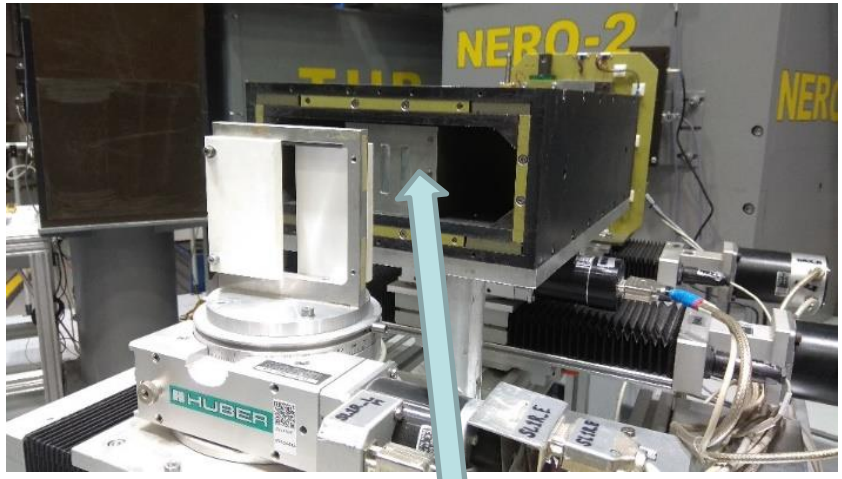
High-resolution neutron reflectometer NERO-2



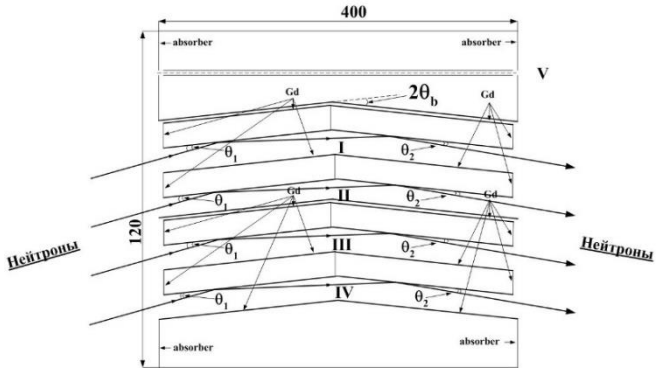
focusing monochromator



collimation 2D-diaphragm

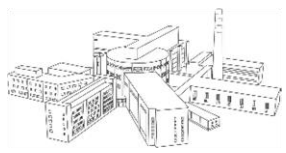


beam former

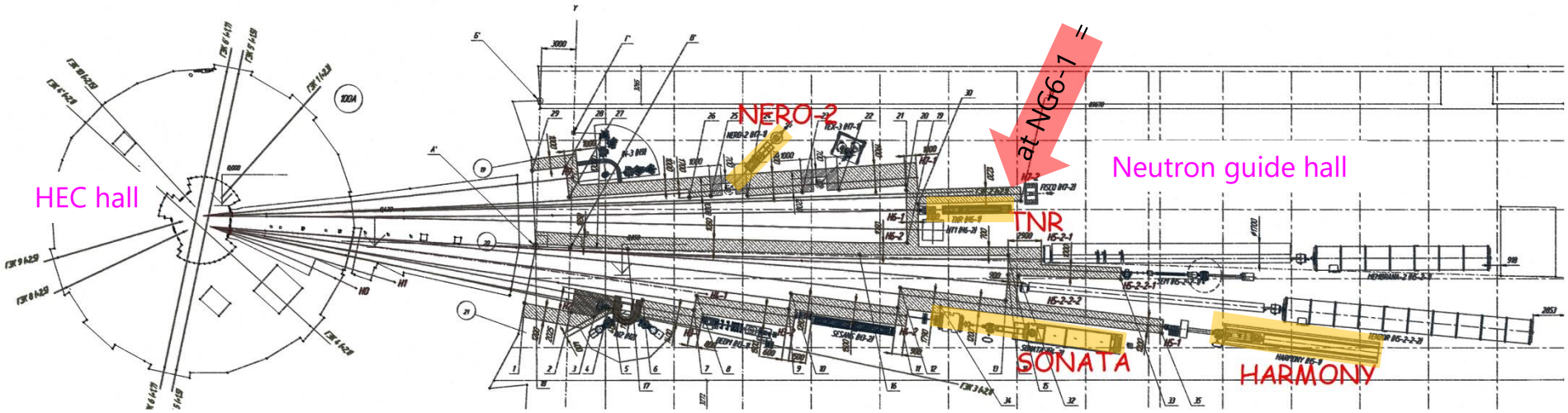


7 plates of 20x20x2 mm^3 HOPG (002) d=3.355 Å, mosaicity 0.66° ($\Delta\lambda/\lambda$ = 2%). Remote adjustments.

(Channels) beams produced:
(I) non-polarized, high resolution
(II) non-polarized, medium resolution
(III) polarized, high resolution
(IV) polarized, medium resolution



Location of the reflectometers at the research reactor PIK



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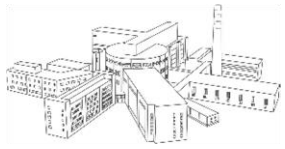
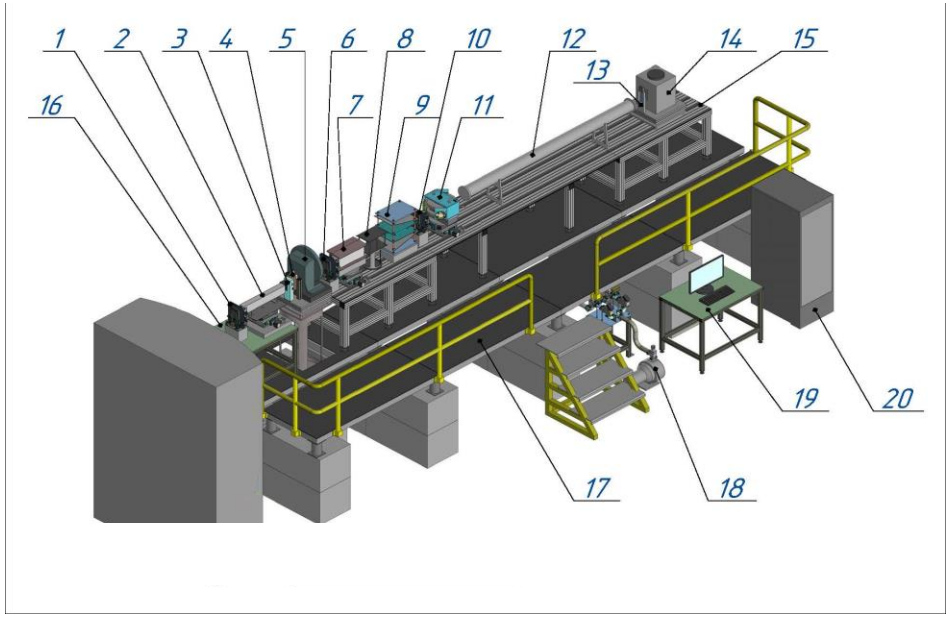


Test neutron reflectometer TNR

Location:
Neutron guide H6-1

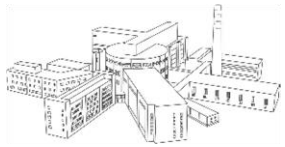


1,6,10 - collimation 2D-diaphragms; 2 – deviating mirror; 3 - shutter; 4 - monitor; **5 - chopper**; **7 - beam former**; 8 – guide field; **9 - flipper**; **11 – sample table with electromagnet**; 12 - vacuum tube; 13 – detector slit; **14 - pencil detector**; 15 – detector platform; 16– vibration-resistant slipway; 17- staff slipway; 18– vacuum post; 19 – control computer; 20 – electronics racks

CONCEPT

- provision of measuring in time-of-flight and constant wavelength modes, with non-polarized and polarized neutrons, by using the beam former unit;

- measurement regimes >> geometry: slit; technique: time-of-flight/constant wavelength; beam: non-polarized/polarized.



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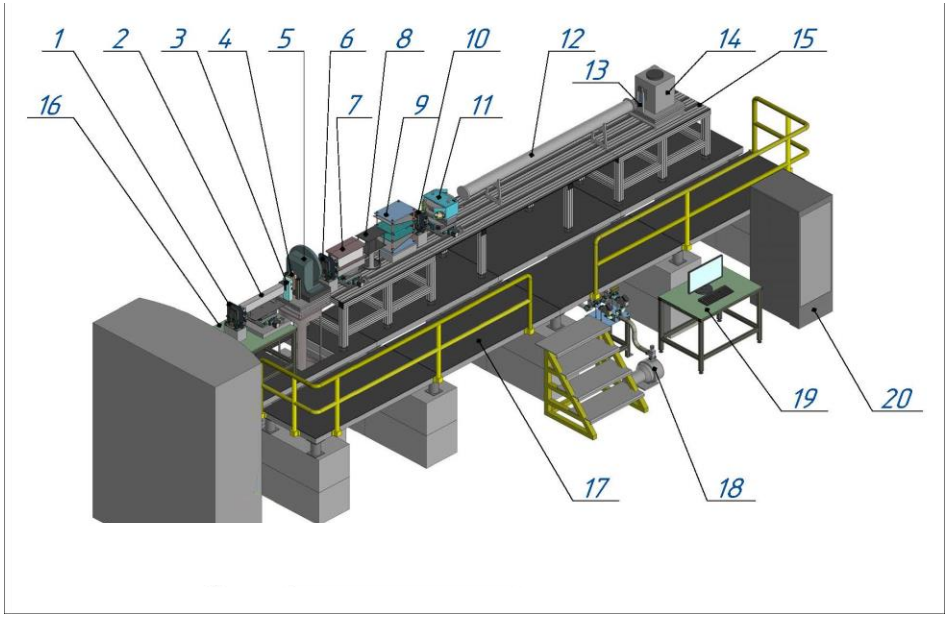

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Neutron guide H6-1

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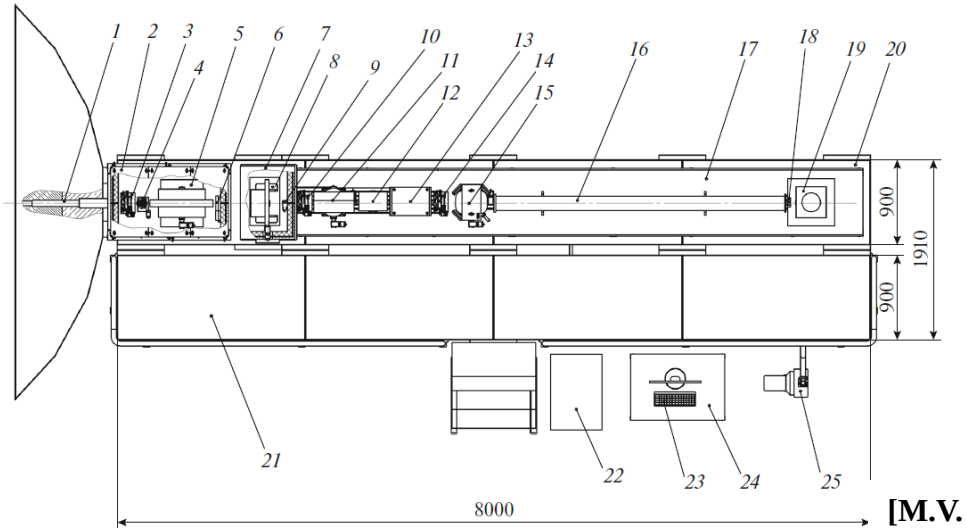
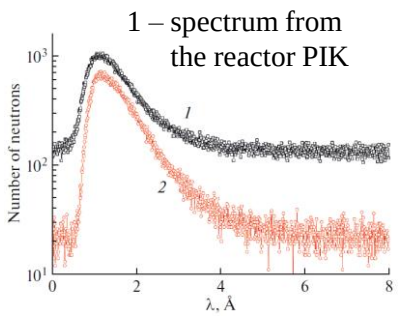
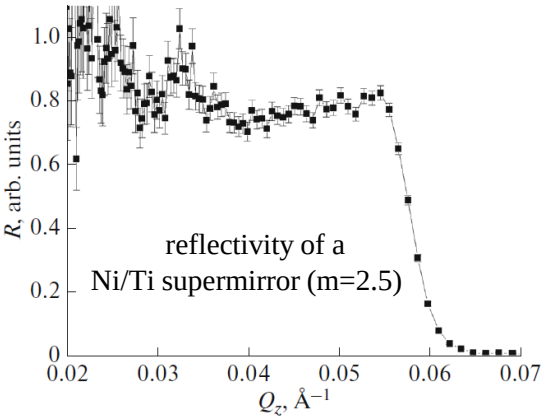
Test neutron reflectometer TNR

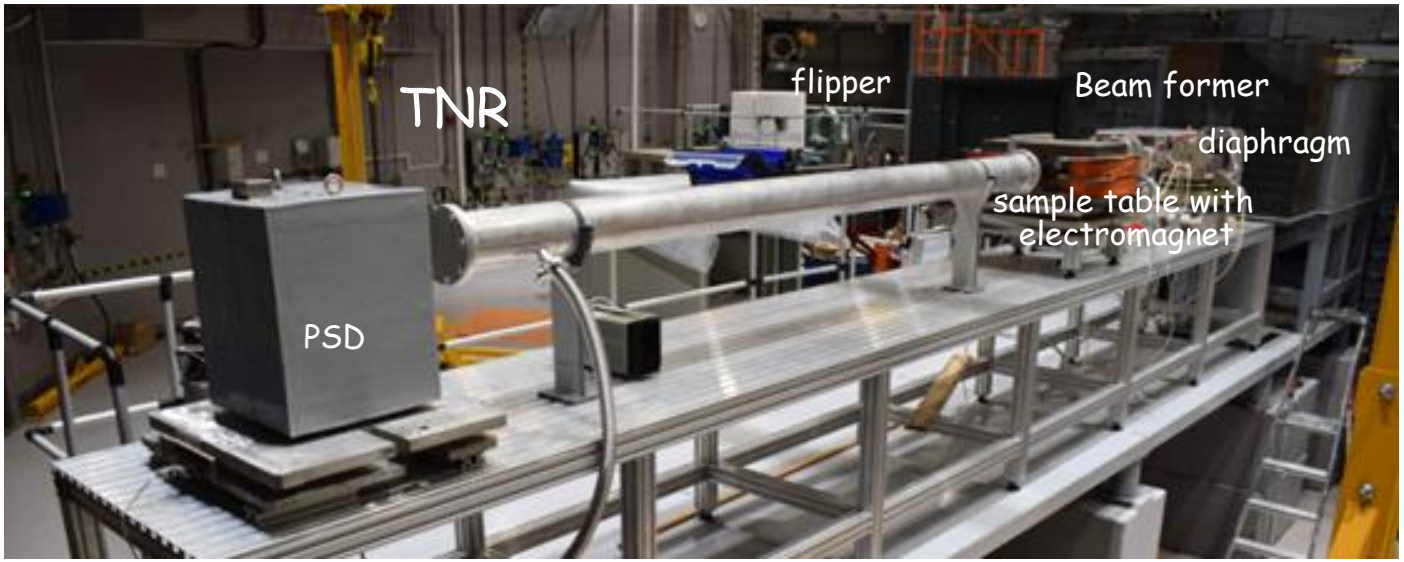






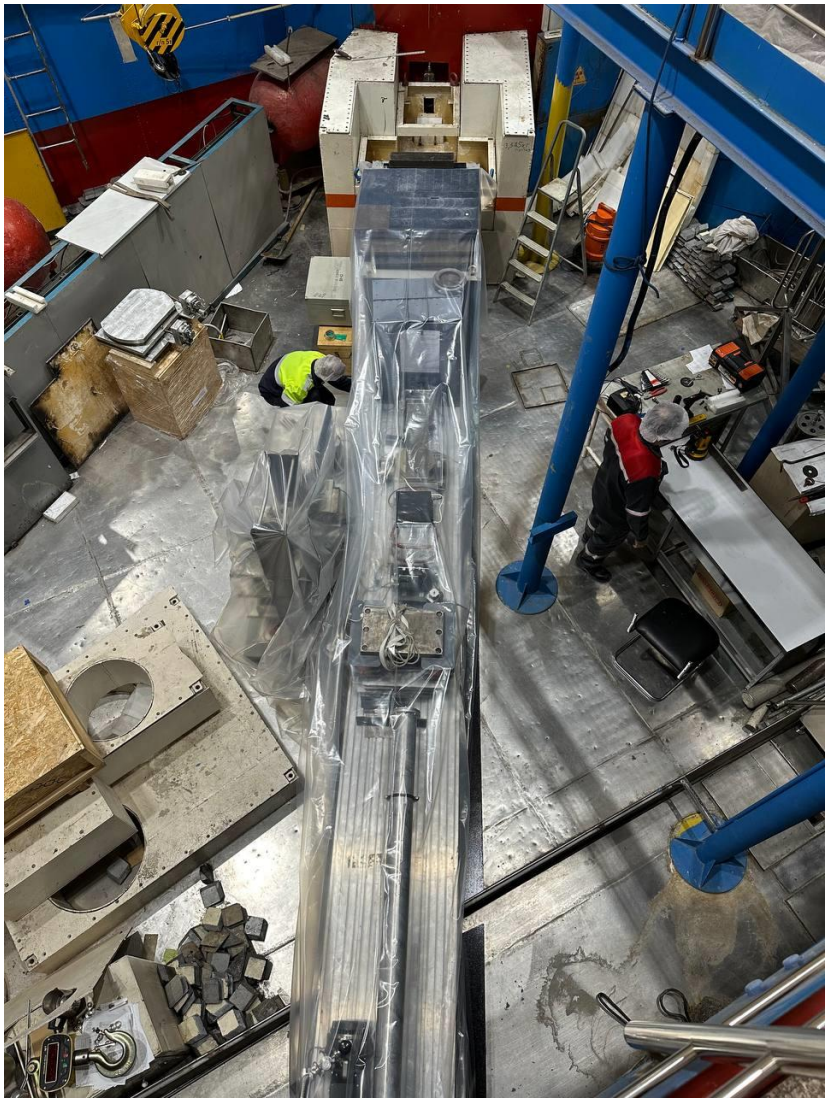
[M.V. Dyachkov, V.A. Matveev, V.G. Syromyatnikov, V.V. Tarnavich, V.A. Ulyanov, J. Surf. Invest.: X-ray, Synchr. Neutron Techn. 18 (2024) 887. - First Measurements at Neutron Reflectometers TNR and NERO-2]

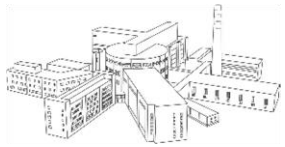
Photo: temporary assembly in the HEC hall to check its functionality and measure the neutron spectrum from the reactor PIK



Test neutron reflectometer TNR

Photo: temporary assembly ongoing
@ channel HEC-7 of reactor IRT-T
(TPU, Tomsk, Russia)





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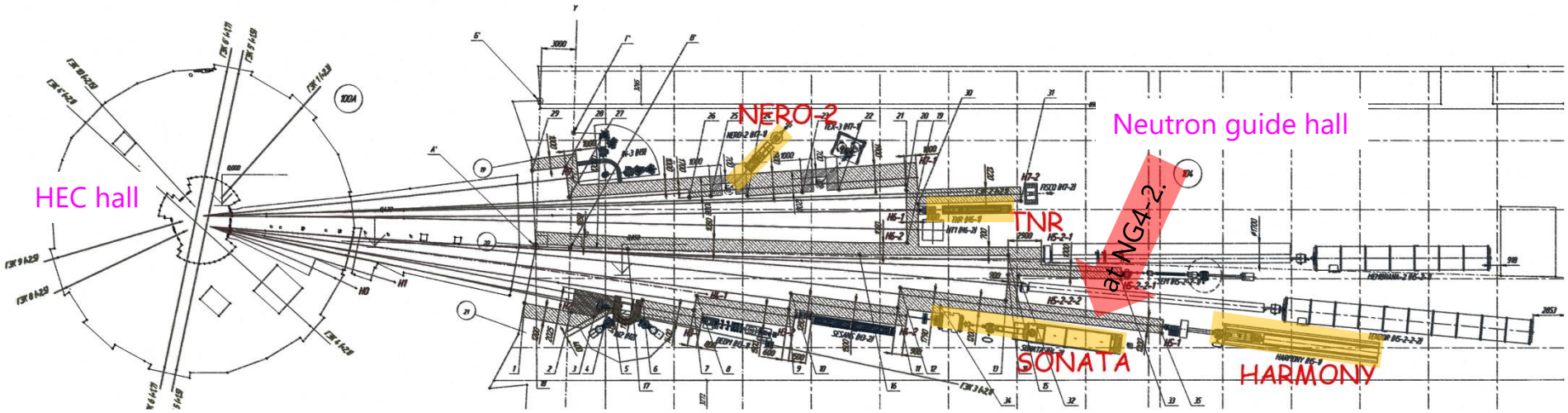

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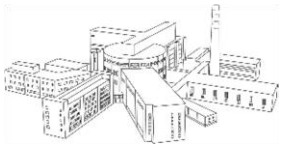
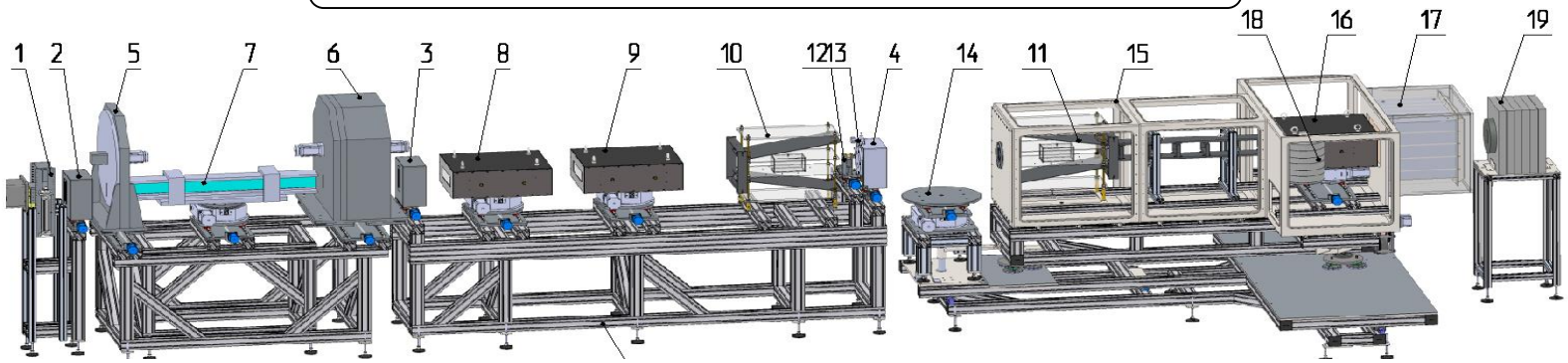


High-flux neutron reflectometer SONATA

Location:
Neutron
guide H4-2



1 - shutter; **2,3,4 – 2D-diaphragms**; **5,6 – chopper units**; **7- transmission filter**; **8,9 - beam combiner units**; **10,11 – flippers**; 12 - attenuator; 13 – monitor; **14 - sample unit**; 15 - detector arm; **16 – fan analyzer**; **17 – PSD**; 18 – pencil detector; 19 – beam stop

CONCEPT

- provision of selecting the wavelength resolution and cutting off the background slow neutrons in the time-of-flight measurement mode by using a special chopper system;

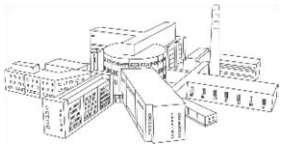
- provision of selecting the wavelength and the wavelength resolution in the constant wavelength measurement mode by using the beam combiner,

- realization of the innovative constant Q_z (λ/θ = const) measurement mode;

- provision of the beam polarization by using the beam combiner and the polarization analysis in a wide range of angles by using the fan analyzer;

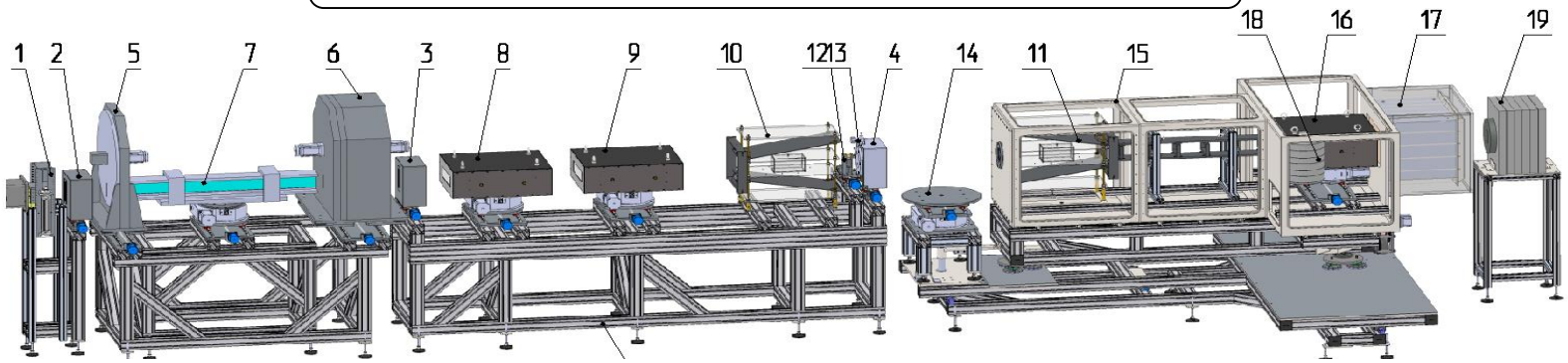
- provision of measurements with 3D-polarization analysis and in innovative schemes of difference phasometry (PNR+) by using a removable platform;

- measurement regimes >> geometry: slit/quasi-point; technique: time-of-flight/constant wavelength/constant Q_z; beam: non-polarized/polarized/3D-polarized.



High-flux neutron reflectometer SONATA

Location:
Neutron
guide H4-2



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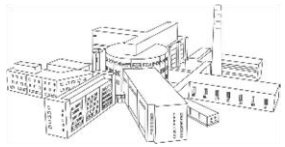
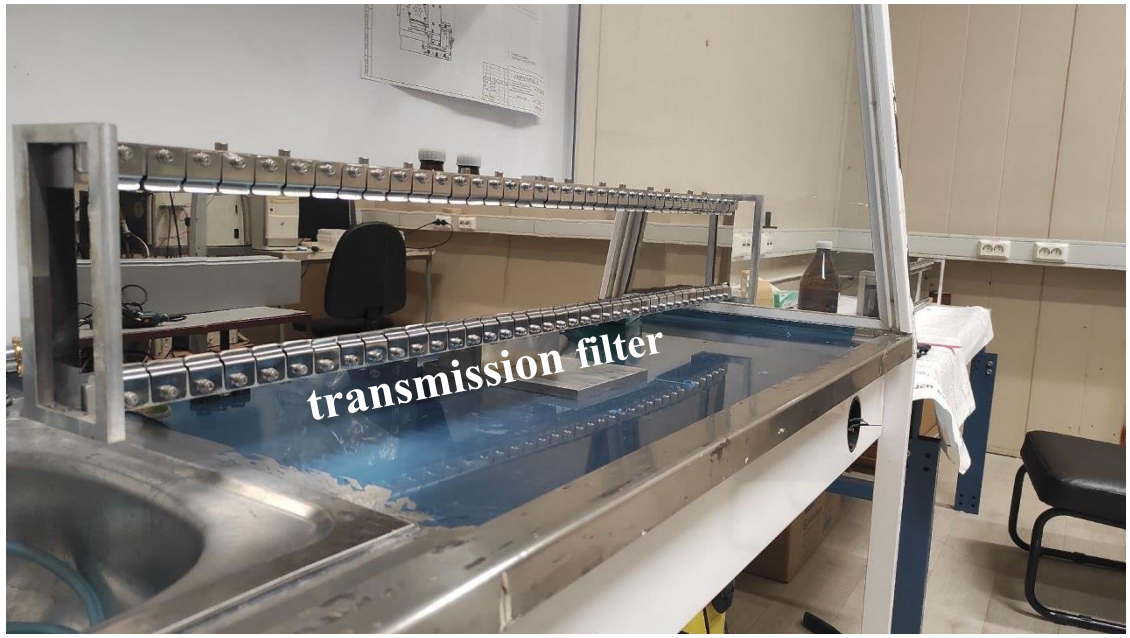
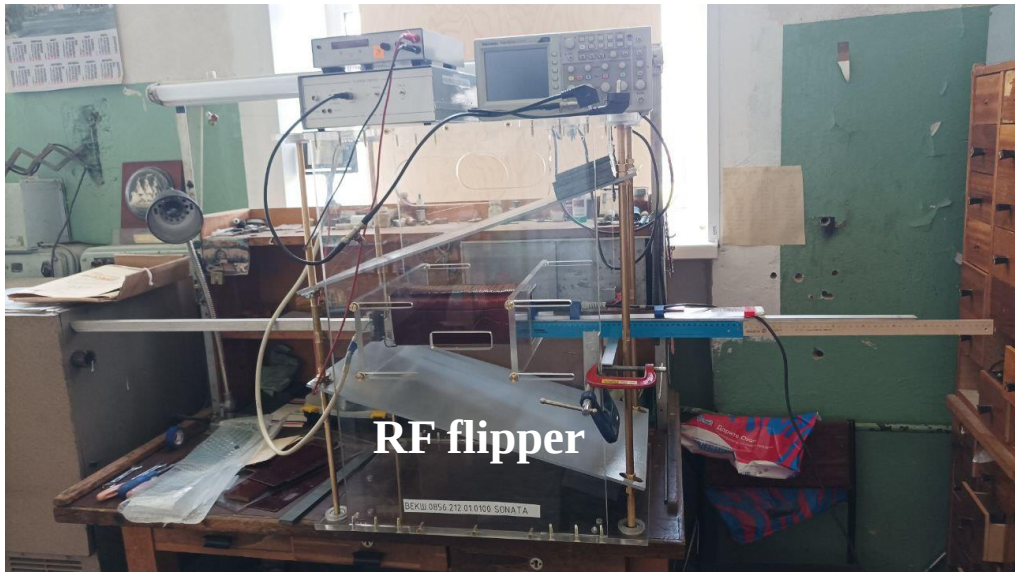
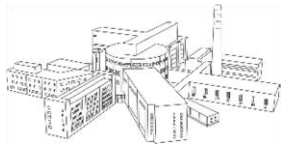
Specifications	Application
• sample: vertical • measuring technique: TOF, λ=const • range of λ: 0.2 ÷2.5 nm • neutron polarization: P > 95 % • Q_z-range: 0.01 ÷ 10 nm^{-1} • ΔQ\Q~5÷15% (TOF), 3÷10% (λ=const) • detector: 300x300 $мм^2$ • Φ_{inc}~10^8, $4 \cdot 10^7$ (polarized) n/s/cm^2	Study of morphology and magnetism of thin layered and laterally patterned structures; processes at the interfaces between different phases, incl. fast kinetics, for solving fundamental and applied problems in physics, chemistry and biology; attestation of functional nano-materials, nano-systems and nano-technologies.



High-flux neutron reflectometer SONATA







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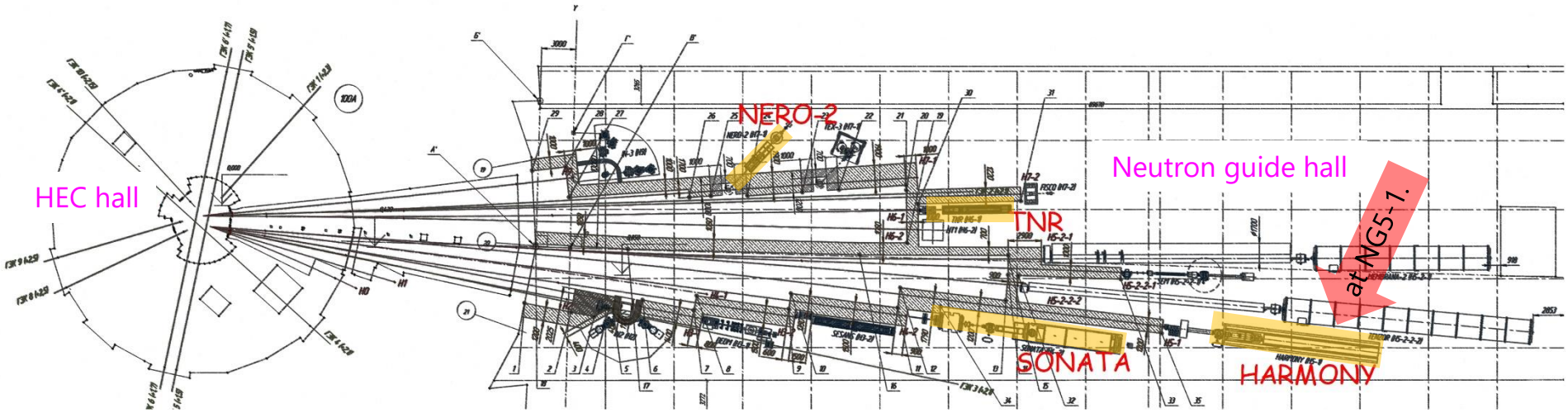

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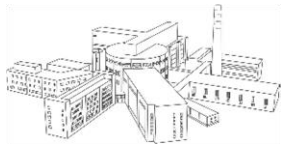
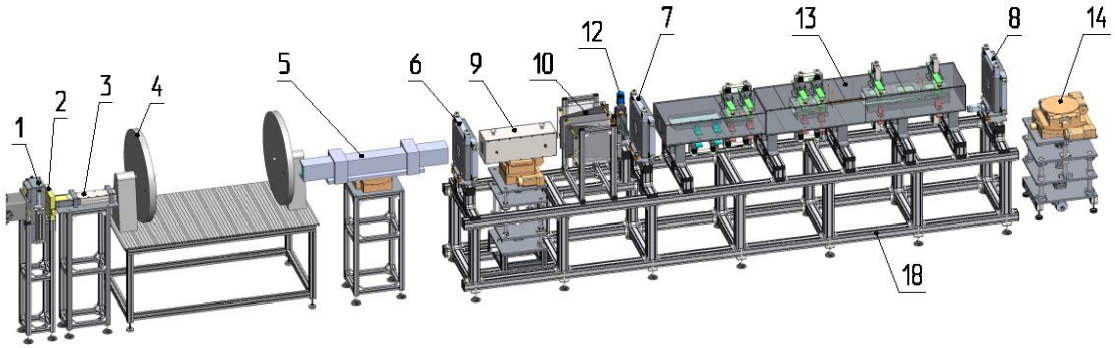
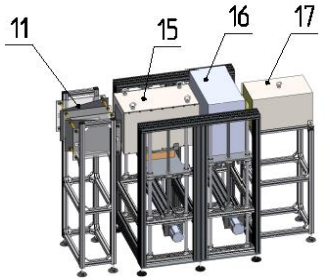


Liquid neutron reflectometer HARMONY

Location:
Neutron
guide H5-1





1 - shutter; 2 - monitor; 3 - collimator; **4 - chopper**; **5 - transmission filter**; **6,7,8 – 2D-diaphragms**; **9 - beam former**; **10,11 - flippers**; 12 - attenuator; **13 - supermirror beam deviator**; **14 – sample unit**; **15 – fan analyzer**; **16 - PSD**; 17 - beam stop; 18 – support frame

CONCEPT

- provision of scattering neutrons at the horizontal sample surface;

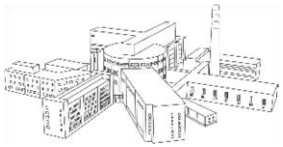
- provision of selecting the wavelength resolution by using the chopper system and cutting off the background slow neutrons by using the transmission filter;

- provision of measuring at three glancing angles by using a beam deflector, thus covering a wide Q-range in the time-of-flight mode;

- provision of the choice of measuring with the beam incident onto the sample surface from above or below by using the beam deflector;

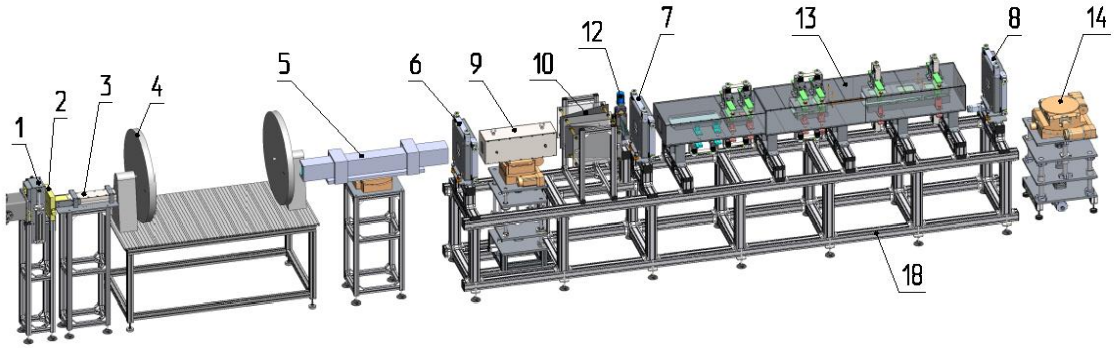
- provision of the beam polarization by using the beam former and the polarization analysis in a wide range of angles by using the fan analyzer;

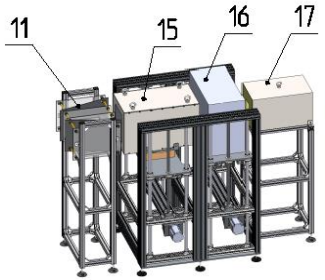
- measurement regimes >> geometry: slit/quasi-point; technique: time-of-flight; beam: non-polarized/polarized.



Liquid neutron reflectometer HARMONY

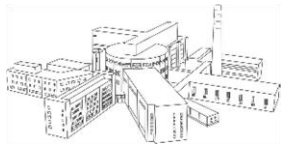
Location:
Neutron
guide H5-1





1 - shutter; 2 - monitor; 3 - collimator; **4 - chopper**; **5 - transmission filter**; **6,7,8 – 2D-diaphragms**; **9 - beam former**; **10,11 - flippers**; 12 - attenuator; **13 - supermirror beam deviator**; **14 – sample unit**; **15 – fan analyzer**; **16 - PSD**; 17 - beam stop; 18 – support frame

Specifications	Application
• sample: horizontal • measuring technique: TOF • range of λ: 0.2 ÷2.0 nm • neutron polarization: P > 95 % • Q_z-range: 0.05 ÷ 3.5 nm^{-1} • $\Delta Q\backslash Q$ ~ 4÷10% (TOF) • detector: 300x300 $мм^2$ • Φ_{inc}~10^7, $4 \cdot 10^6$ (polarized) $n/s/cm^2$	Study of physical and chemical properties of the boundaries with the liquid phase, biomembranes etc. in biology, phase transitions, physics and chemistry of soft matter, kinetics of chemical reactions and bioprocesses, mechanisms of their activation, ordering of nanoparticles, diffusion and relaxation phenomena in assemblies of layered liquids.



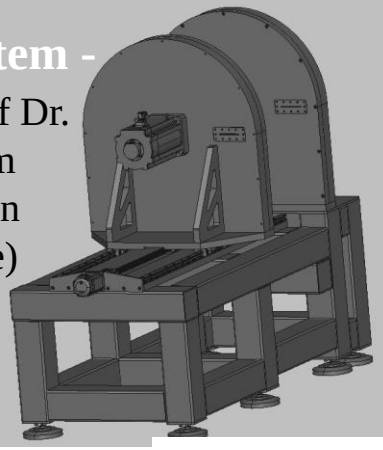
Liquid neutron reflectometer HARMONY

Design Features to study liquids

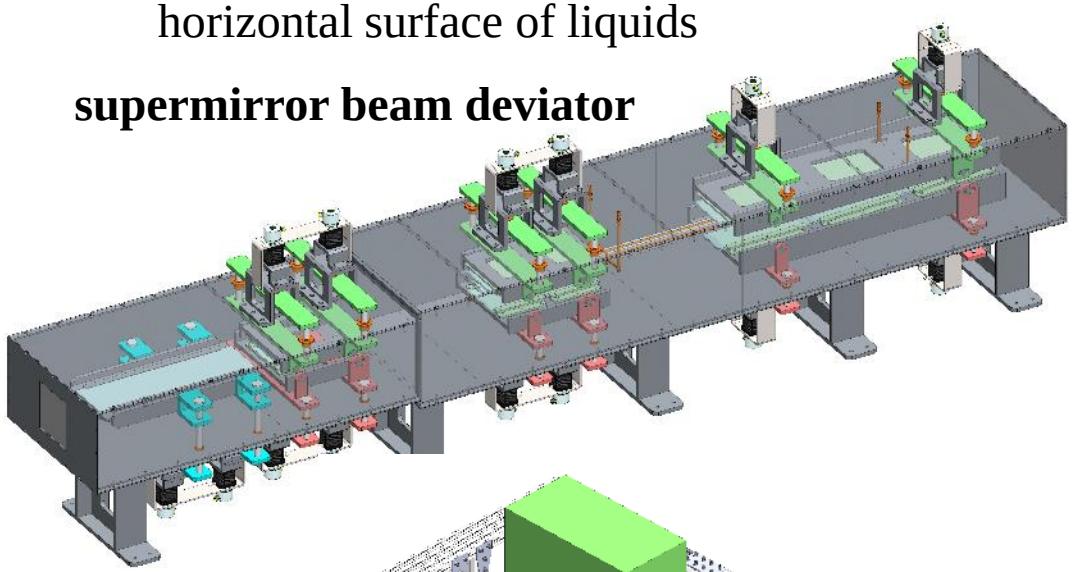
horizontal beam cross-section

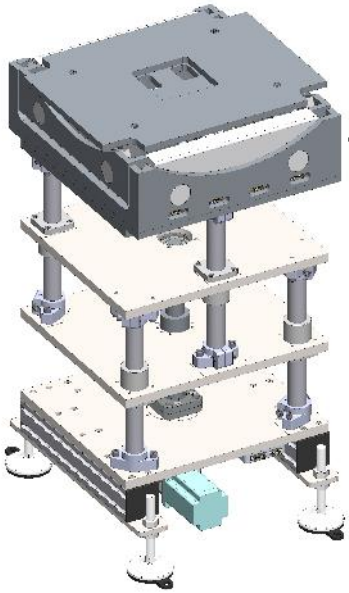
horizontal surface of liquids

chopper system -
(participation of Dr. Wang Ping from China Spallation Neutron Source)

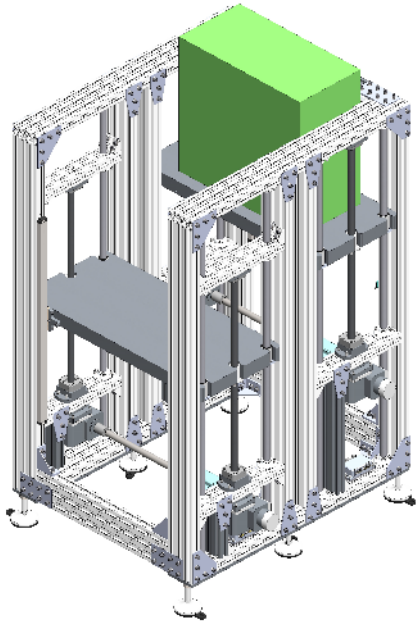


supermirror beam deviator

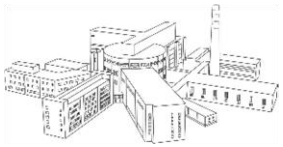




- sample unit



- detector unit

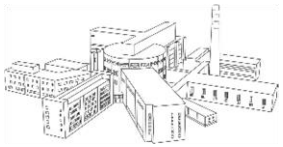


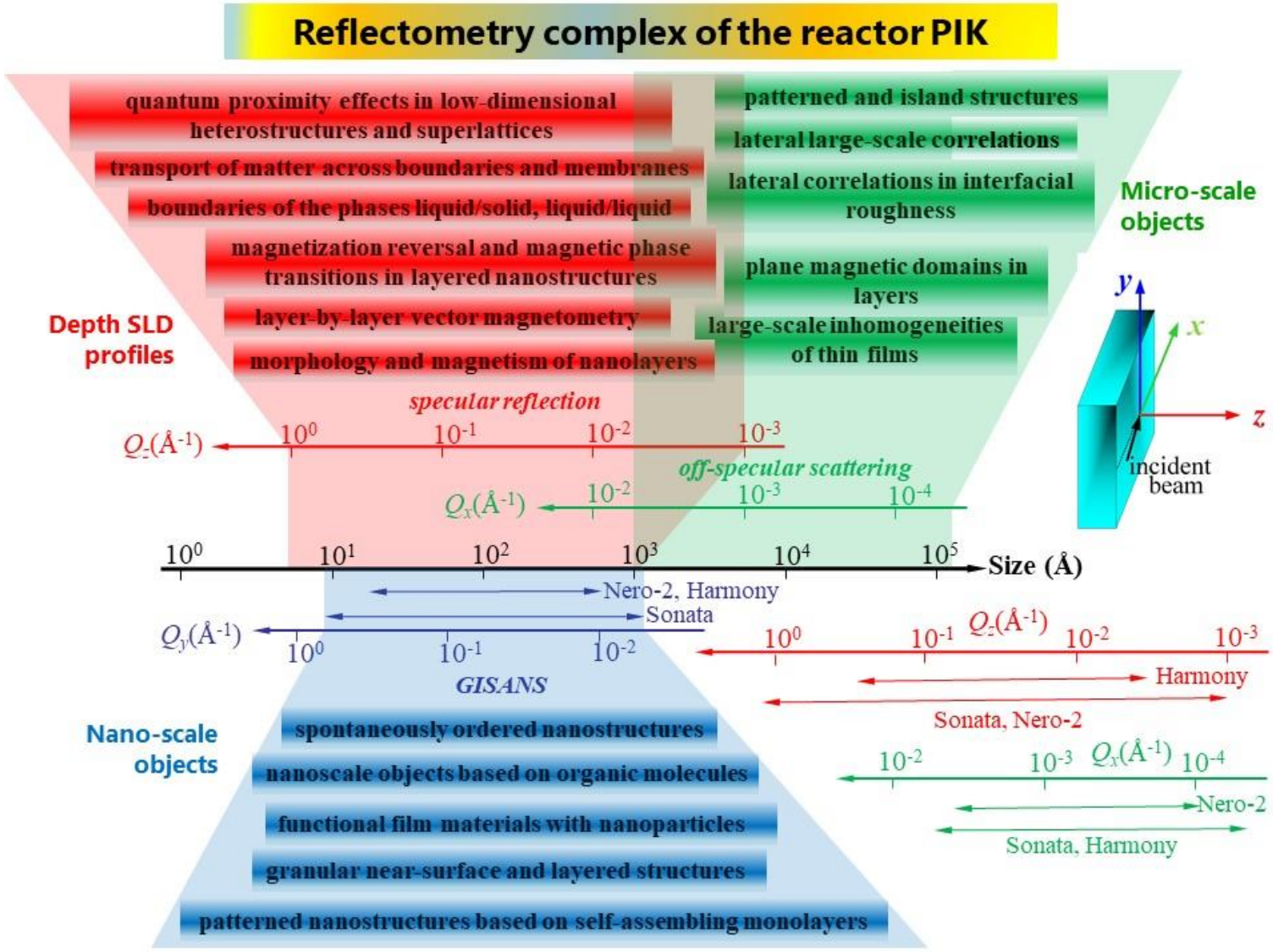
Reflectometers at the reactor PIK

Summary Table of Specifications

	SONATA	HARMONY	NERO-2	TNR
Sample	vertical	horizontal	vertical	vertical
Geometry	slit/quasi-point	slit/quasi-point	slit/quasi-point	slit
Measuring technique	TOF λ=const Q_z=const	TOF	λ=const GID	TOF λ=const
Beam	non-polarized polarized 3D-polarized	non-polarized polarized	non-polarized polarized	non-polarized polarized
Range of λ	0.2 ÷2.5 nm	0.2 ÷2.0 nm	0. 52 (0.25) nm	0.1 ÷1.0 nm
Analyzer	fan 300 × 100 mm^2	fan 100 × 300 mm^2	fan 250 × 100 mm^2	-
PSD: window, resolution	300 × 300 mm^2 2 × 3 mm^2	300 × 300 mm^2 3 × 2 mm^2	250 × 250 mm^2 2 × 5 mm^2	pencil
Q_z-range	0.01 ÷ 10 nm^{-1}	0.05 ÷ 3.5 nm^{-1}	0.01 ÷ 10 nm^{-1}	0.05 ÷ 5 nm^{-1}
Resolution, Δq\q	5÷15% (TOF) 3÷10% (λ=const)	4÷10%	2-3 % 5-7 %	5÷10% (TOF) 3÷10% (λ=const)

The reflectometry complex should allow the choice of adequate measurement scheme, required range of momentum transfers, and optimal balance between resolution and flux at the sample. All reflectometers have the polarized beam option.





Expected range of sizes available for measurements at the reflectometry complex of the reactor PIK and possible research objects. Three components of Q feature three channels of scattering: (Q_z) specular reflection is informative of SLD depth profiles, (Q_x) off-specular scattering is informative of micro-scale objects and (Q_y) GISANS is informative of nano-scale objects

Thanks for your attention!