Kurchatov synchrotron: present state and upgrade program

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Talk outline

- Some historical points
- Present research
- Upgrade program
- New departments grown around synchrotron: Kurchatov Nano Bio Informatic and Cognitive sciences center- NBIC
- CREMLIN

KURCHATOV INSTITUTE HISTORY

12.04.1943

Laboratory № 2

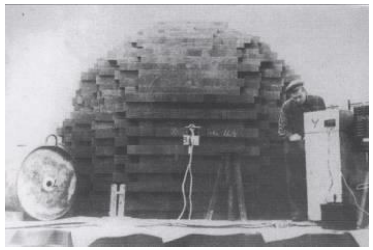
Academy of Sciences of the USSR

10.11.1956

Institute of Atomic Energy

21.11.1991

Russian Research Center Kurchatov Institute



1946 reactor, the first reactor in Eurasia F-1 startup

1954 г. – the first in the world atomic power plant startup (Obninsk)

1958 г. – the second in the world nuclear – powered submarine "Leninsky Komsomol"

1959 г. - the first in th world atomic ice-breaker "Lenin"

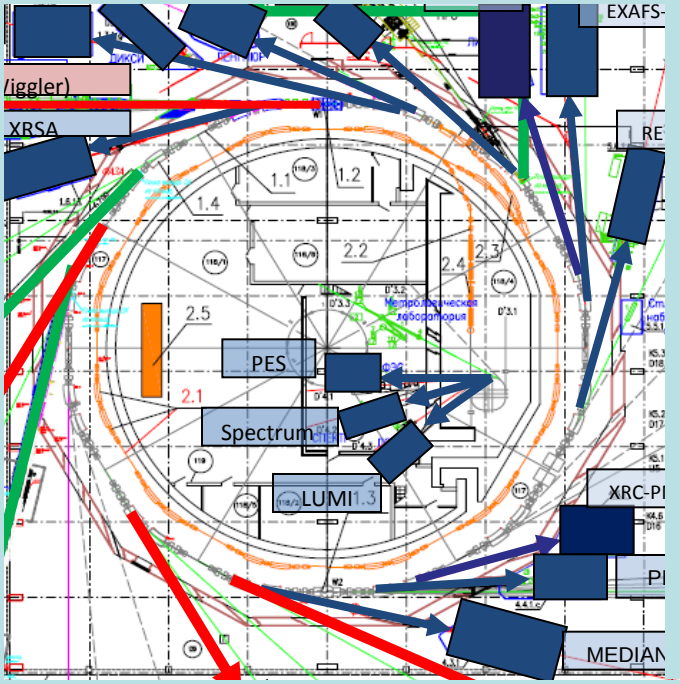
Kurchatov synchrotron. Site before construction started. 1985

Operational since 1999

Renovated in 2007-2010

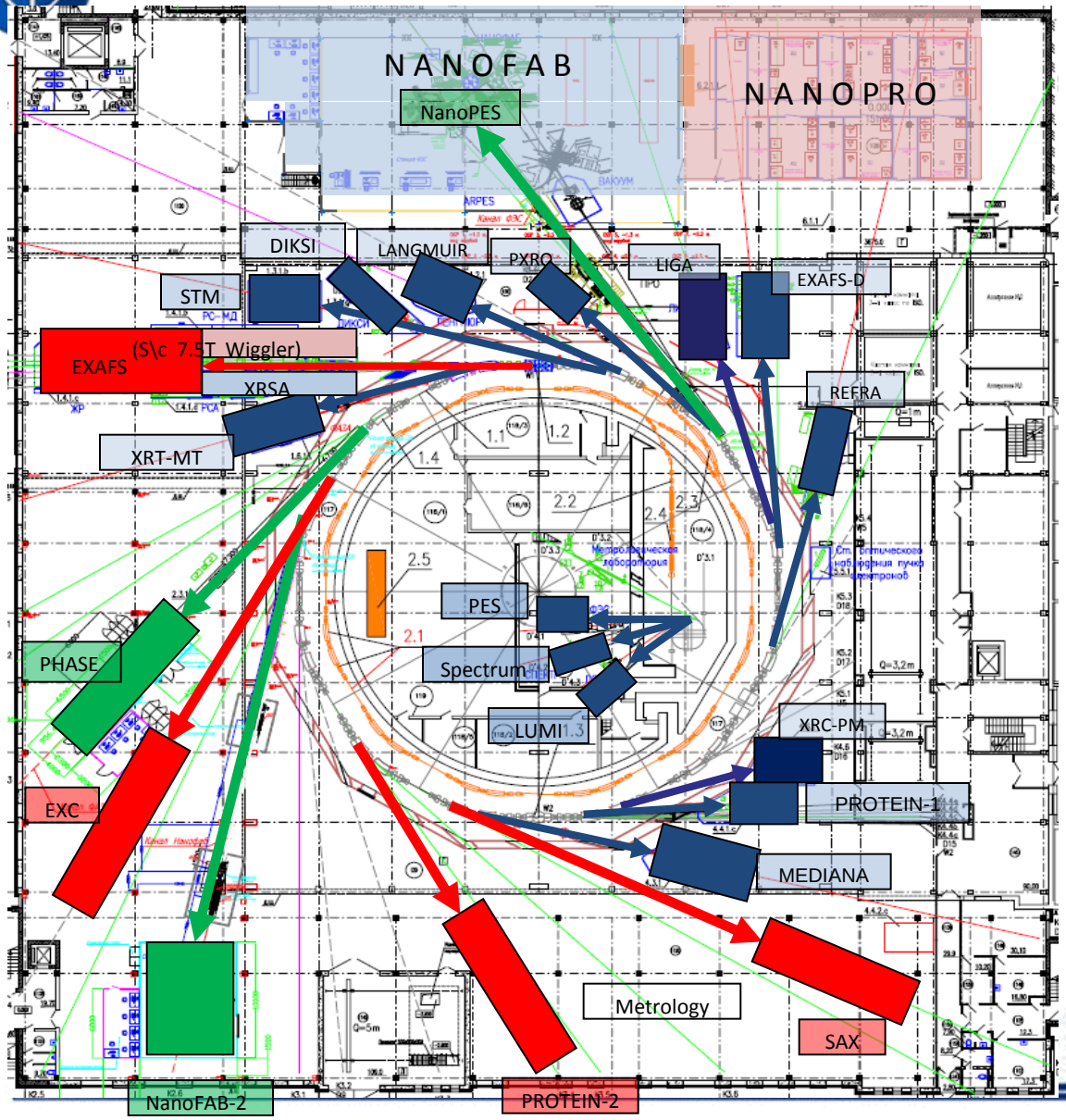
15 beamlines operatonal

Experimental hall
before…



Beamlines:

Build defore upgade



… after reconstruction

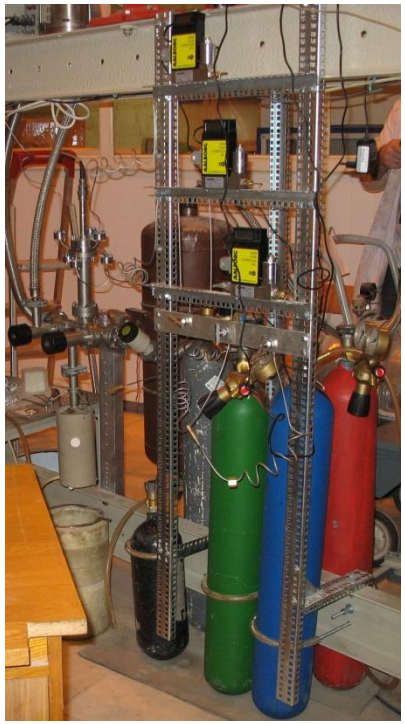
Beamlines:

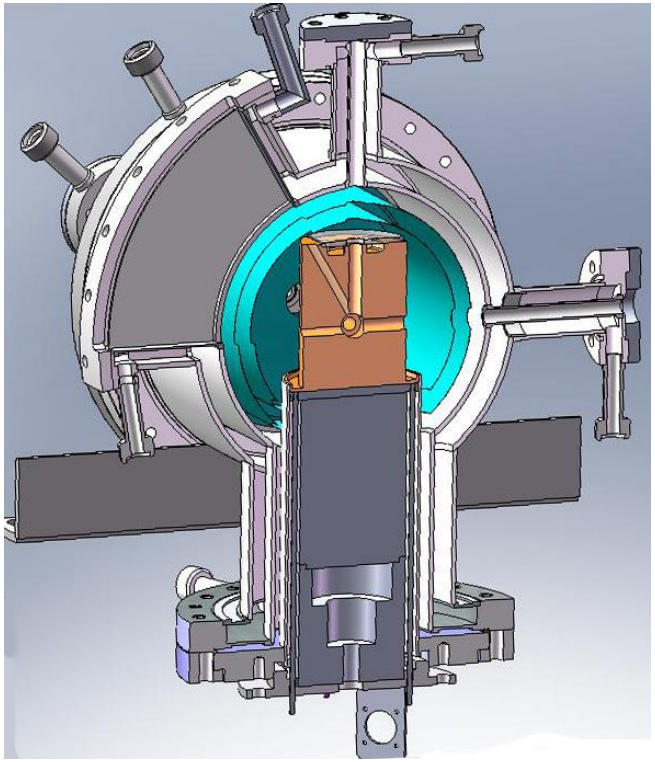
- **Build defore upgade**
- **First step upgrade**
- **Next upgrade step**

Combined use of XAFS, XRD and SAXS

- **XANES** - electronic structure and chemical state of heavy atoms, local environment symmetry
- **EXAFS** - local neighborhood of a given heavy atom
- **XRD** - long-range order in the sample, phase composition, degree of ordering in the sample
- **SAXS** - sizes and forms of pores, second phase segregations and other inhomogeneities with sizes in the region of 1-100 nm

In-situ chamber for catalysis (since 2009)



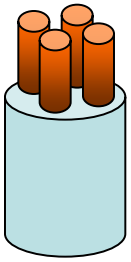


20-550oC

Thermostabilization through the heating current & thermocouple feedback ±1oC

- 3-component gas mixtures
- Inerts: **He, N2, Ar**
- Oxidation and reduction: **O2, H2**
- Catalytic substrate: **CO, CH4, etc.**
- Vacuum 10 Pa

4 × 350 W

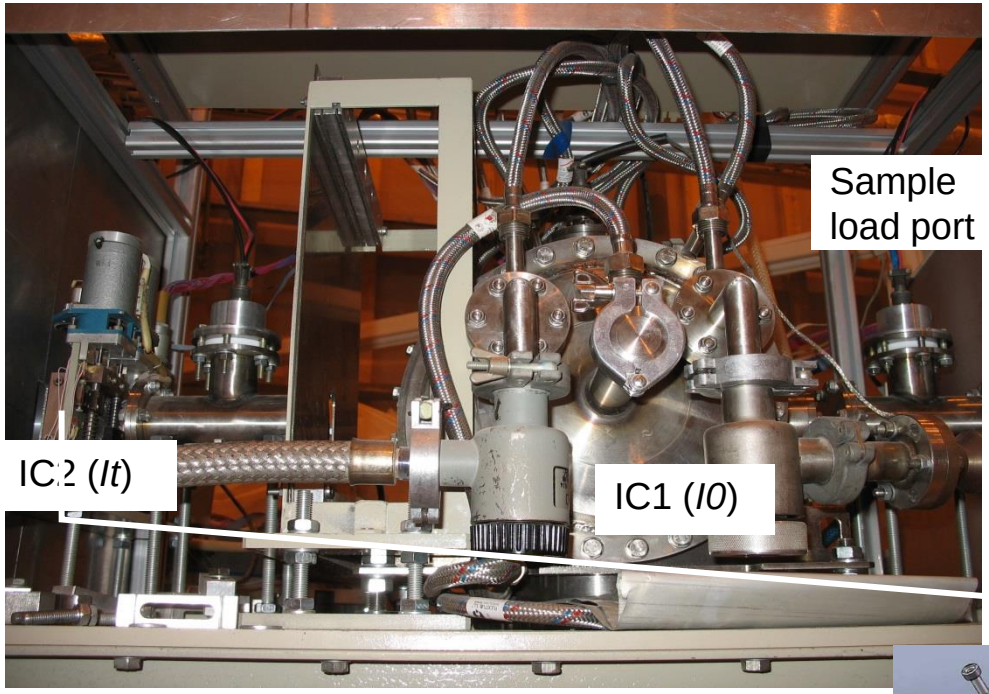


Cooling down to -130oC with a flow of cold N2 gas

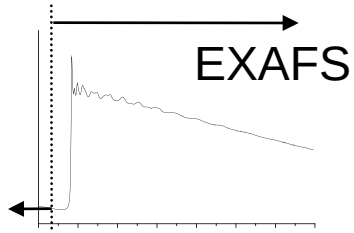
In-situ chamber measurement system

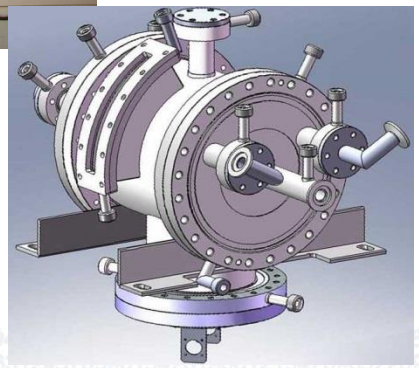
Image Plate holder

γ-Al2O3



SR



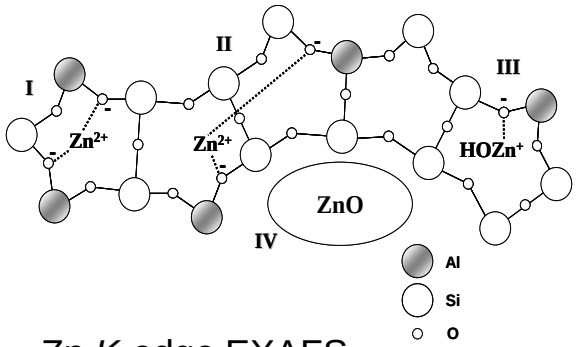


Chemistry: Catalysts, hydrides, fullerenes and their compounds

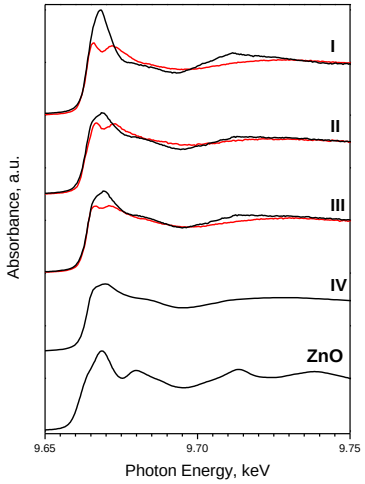
EXAFS

Catalysts nanostructure study
(Zn-activated zeolites for propane aromatization)

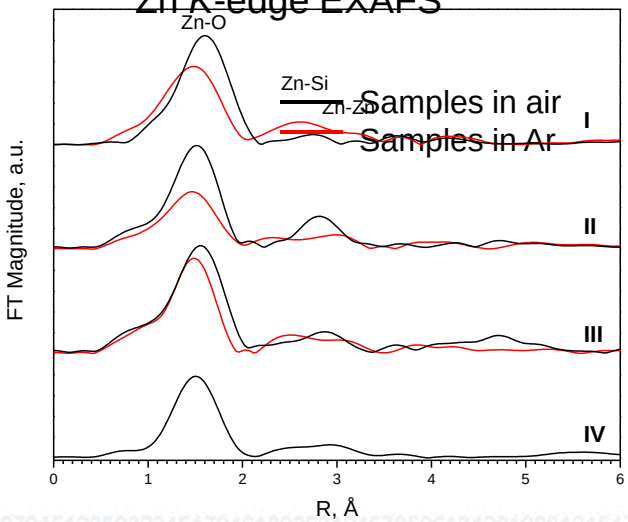
Possible Zn active sites in ZSM-5



Zn *K*-edge XANES

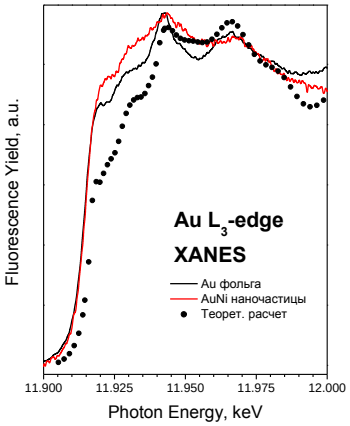


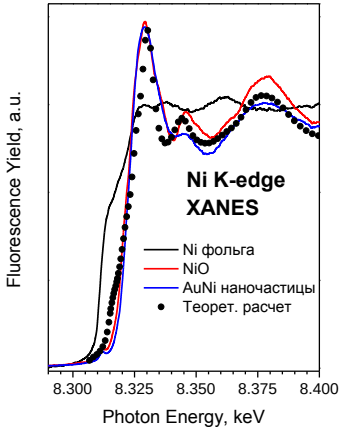
Zn *K*-edge EXAFS



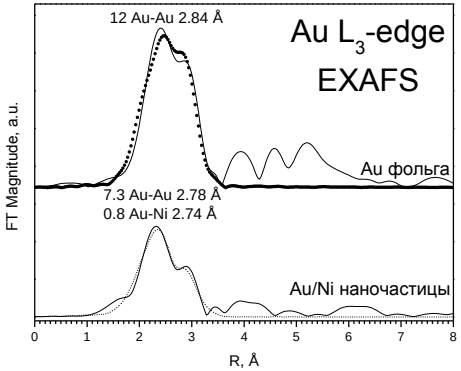
Amorphous nanoparticles

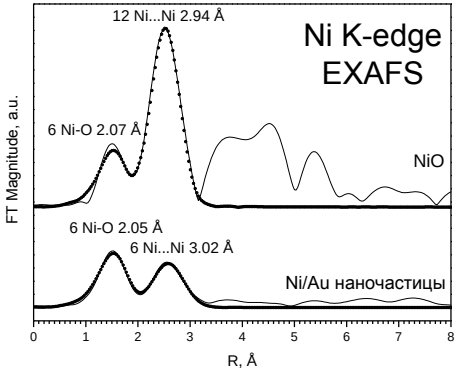
XANES



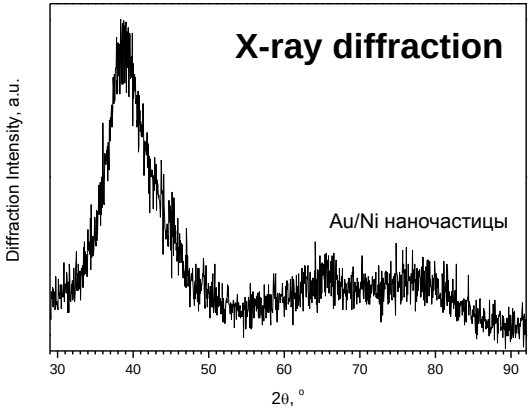


EXAFS

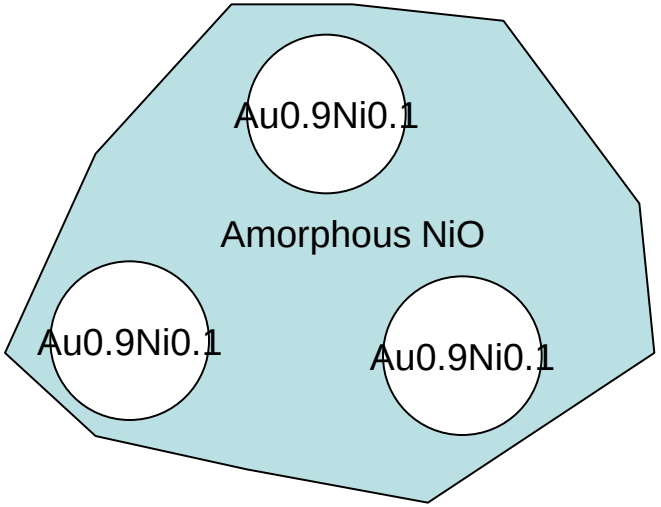


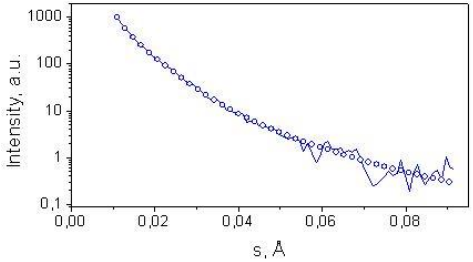


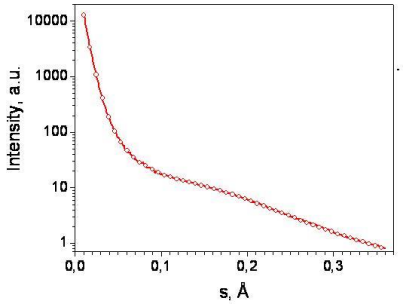
Model of the structure



X-ray diffraction



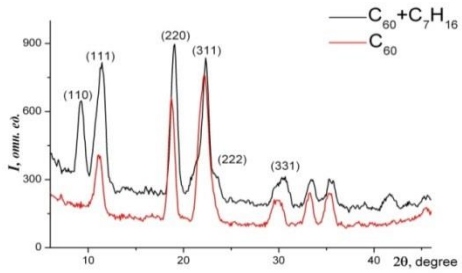




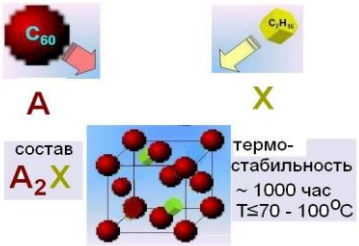
Small angle scattering

Fullerenes and their compounds

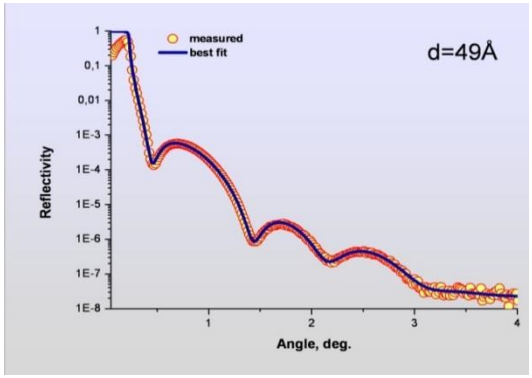
Compounds of fullerenes with burning gases and their derivatives



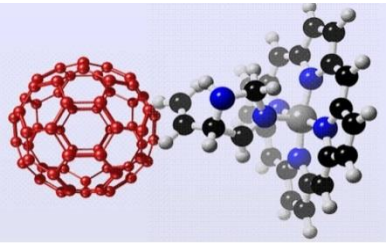
Fullerene – porphyrines dyads



Storage system for liquids and gases

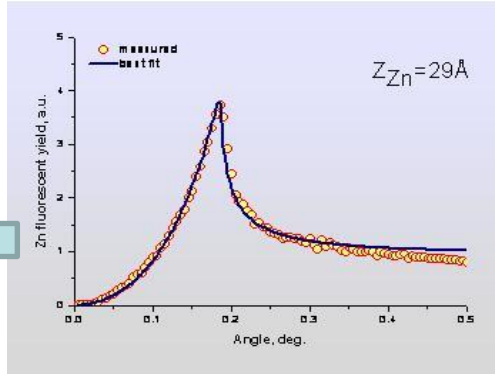


Reflection curve



Porphyrines on substrate

Fullerenes on surface
(Zn – marker)

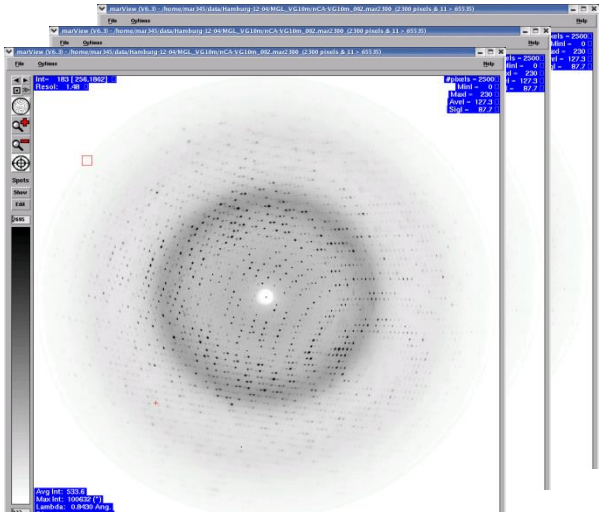


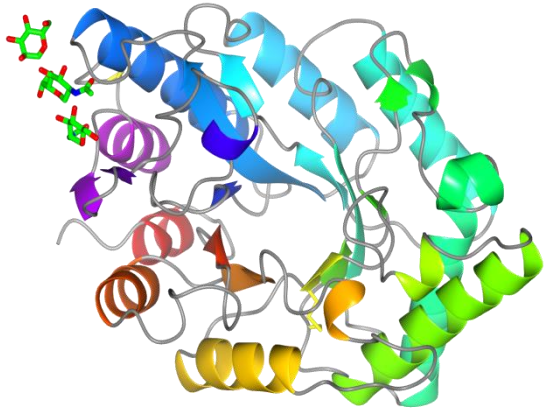
Fluorescence

X-ray diffraction experiments

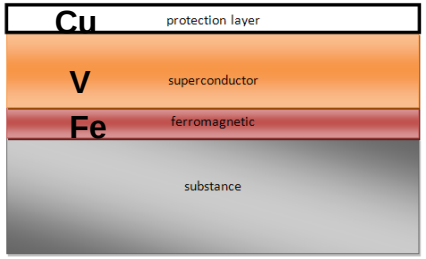
Protein Crystallography

- **Single crystal protein diffraction**
- **18** new structures solved last 2 years

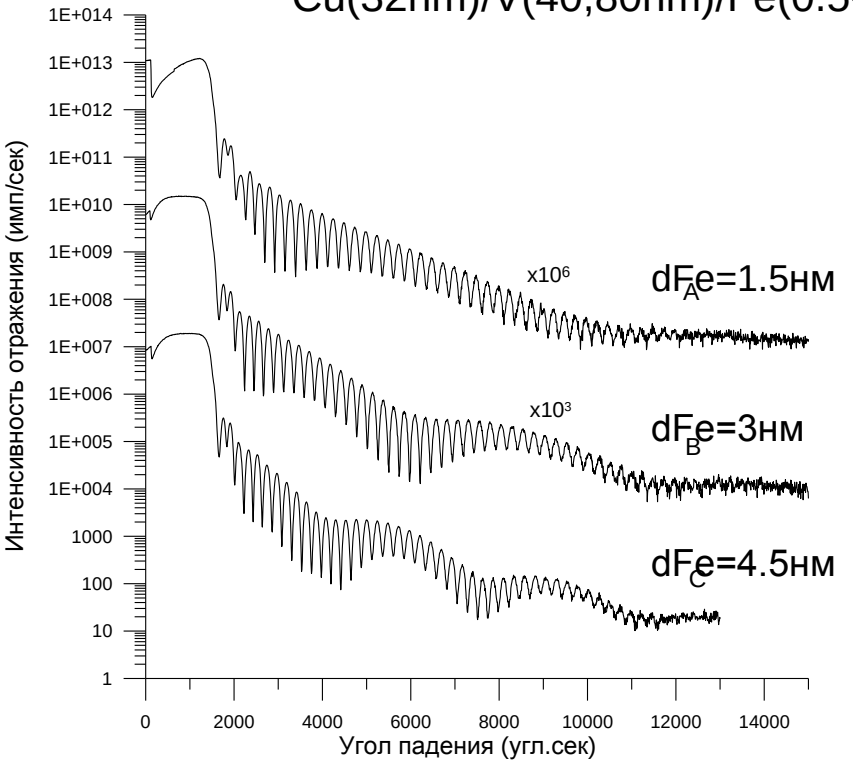




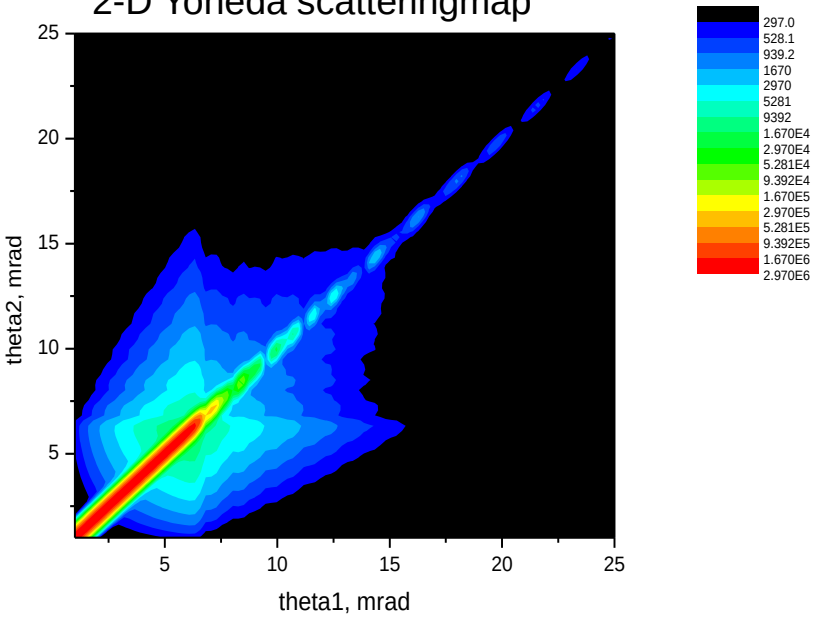
Effects in layered structures superconductor/ferromagnetic



Cu(32nm)/V(40,80nm)/Fe(0.5-4nm)/MgO(001)



2-D Yoneda scatteringmap

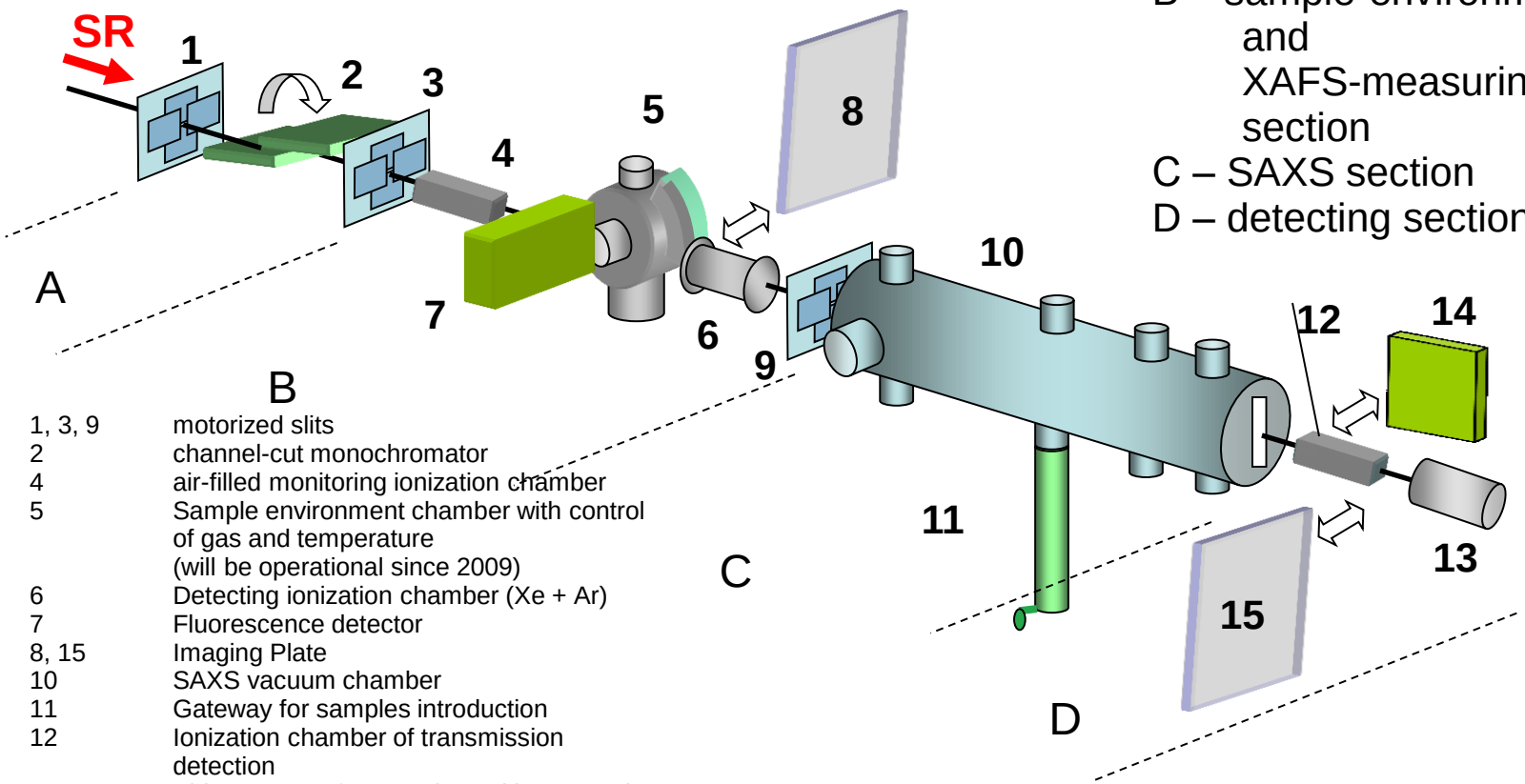


SR based Reflectometry

Diffuse scattering

"Structural Material Science" beamline

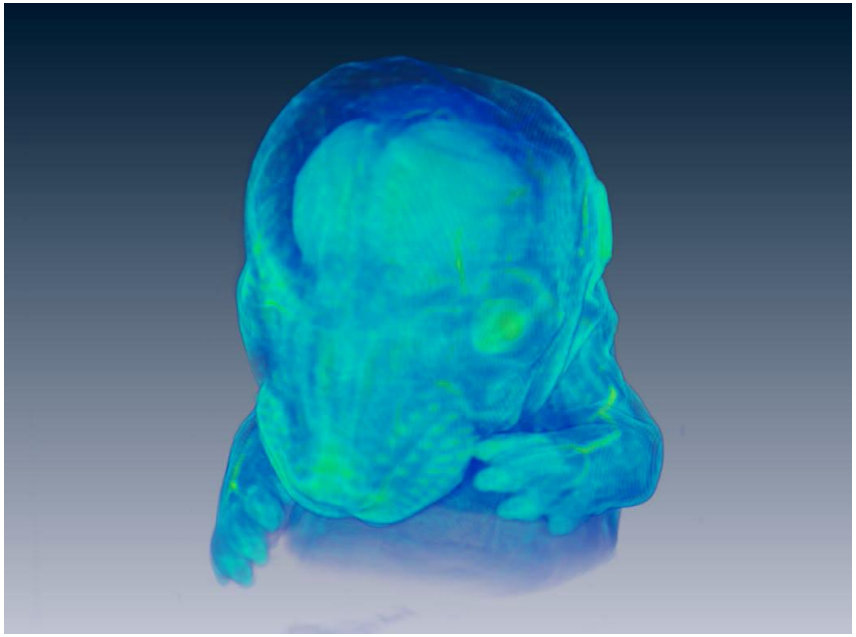
A – beam-defining section
B – sample-environmental and XAFS-measuring section
C – SAXS section
D – detecting section

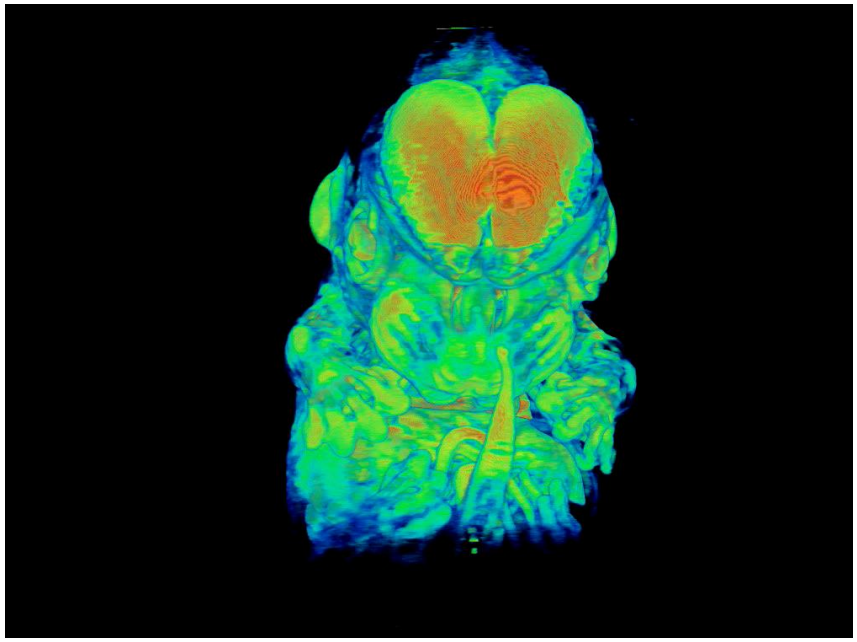


1, 3, 9	motorized slits
2	channel-cut monochromator
4	air-filled monitoring ionization chamber
5	Sample environment chamber with control of gas and temperature (will be operational since 2009)
6	Detecting ionization chamber (Xe + Ar)
7	Fluorescence detector
8, 15	Imaging Plate
10	SAXS vacuum chamber
11	Gateway for samples introduction
12	Ionization chamber of transmission detection
13	Video camera for sample position control
14	1D position sensitive detector

IMAGING

Small animals study

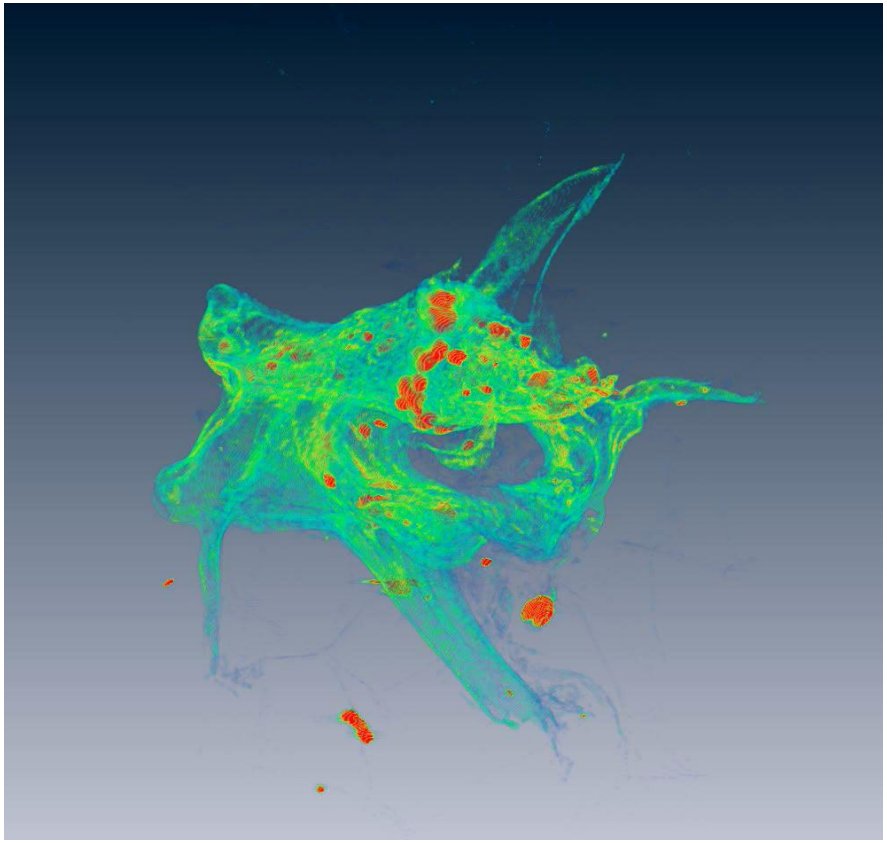




1mm

Newborn mouse and mouse embryo. Vovel size 10x10x10 micrometers

Space calcium loss experiments

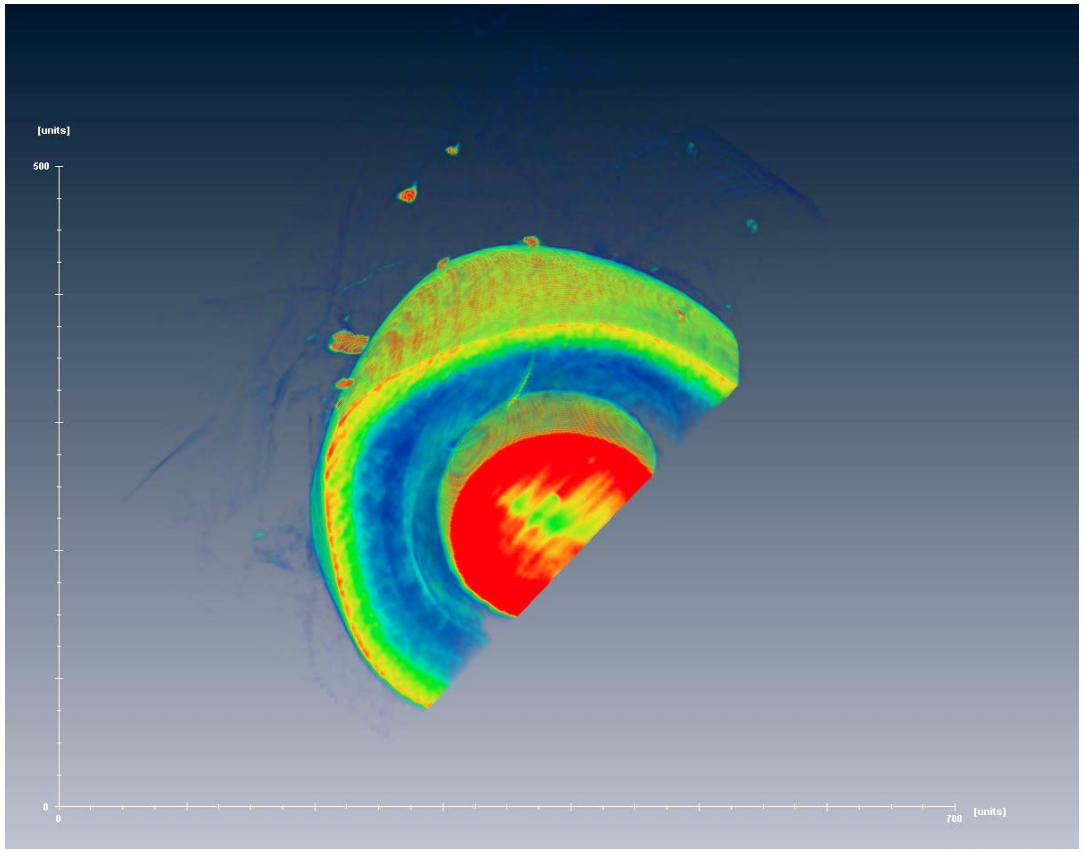


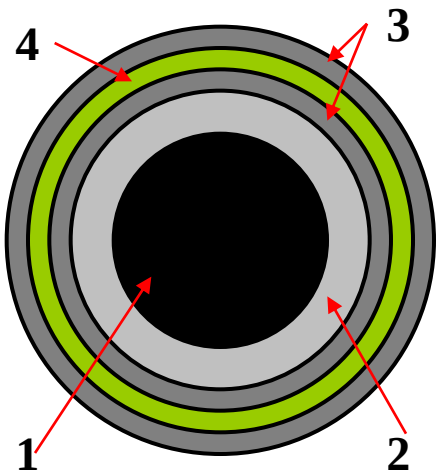
1 mm

Gekko and its spinal bone. Voxel size 2.5 μm

V.E.Asadchikov, R.A.Senin et al. Crystallography Reports, 2012, Vol. 57, No. 5, pp. 700–707.

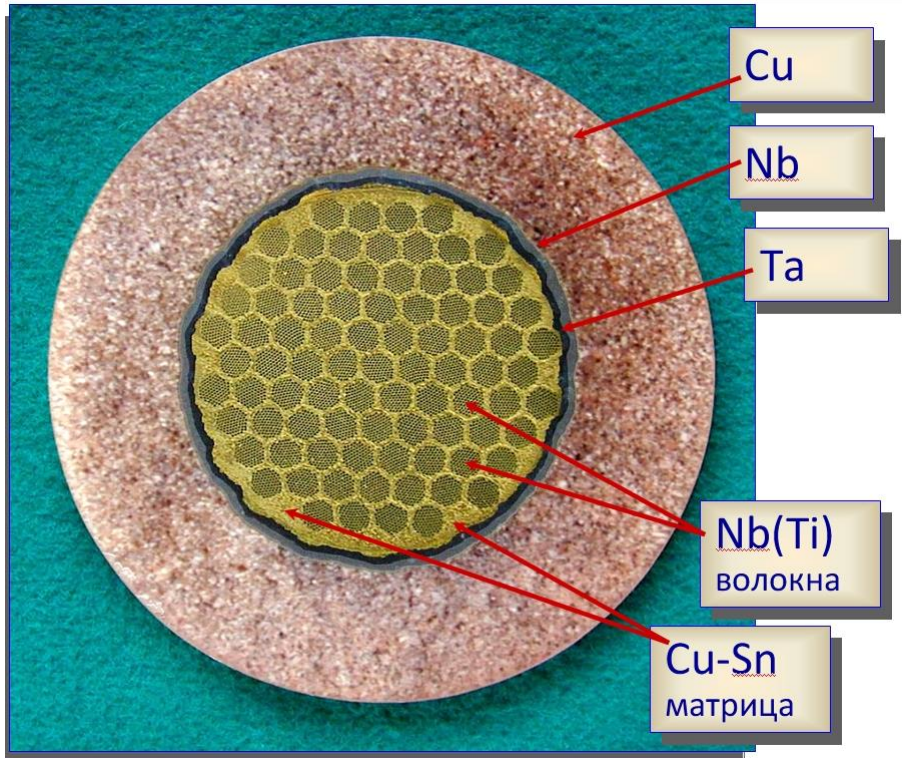
New fuel elements for nuclear power plants

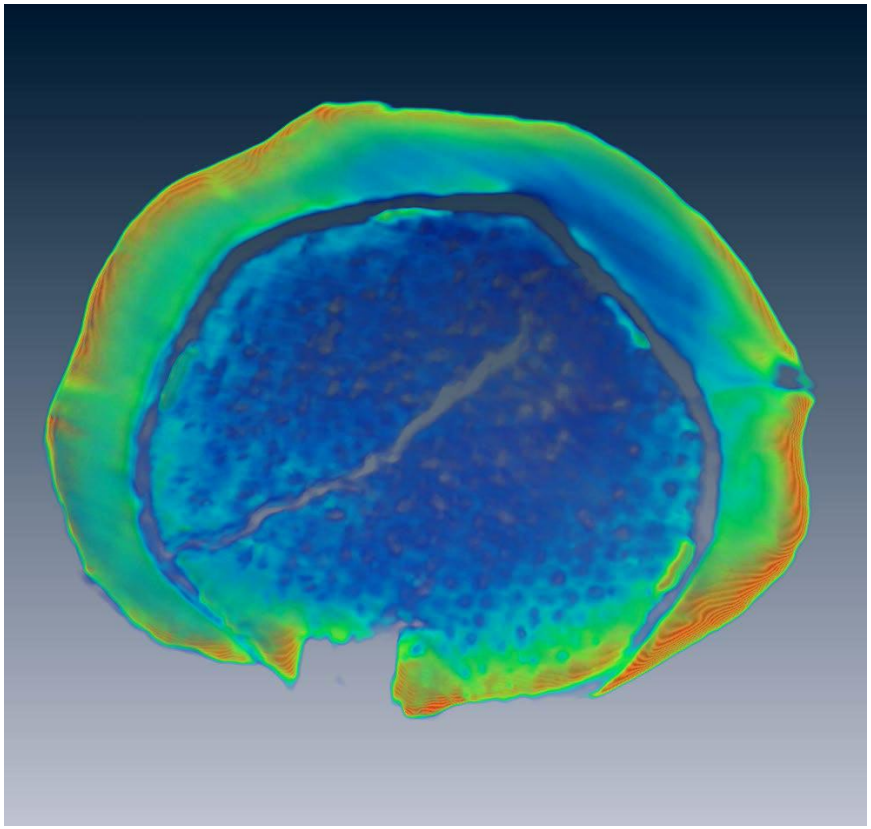




1- UO2, d=500 μm,
2- Low density carbon, h=100μm,
3- High density carbon, h=50 μm, слой
4 - SiC, h=50 μm,

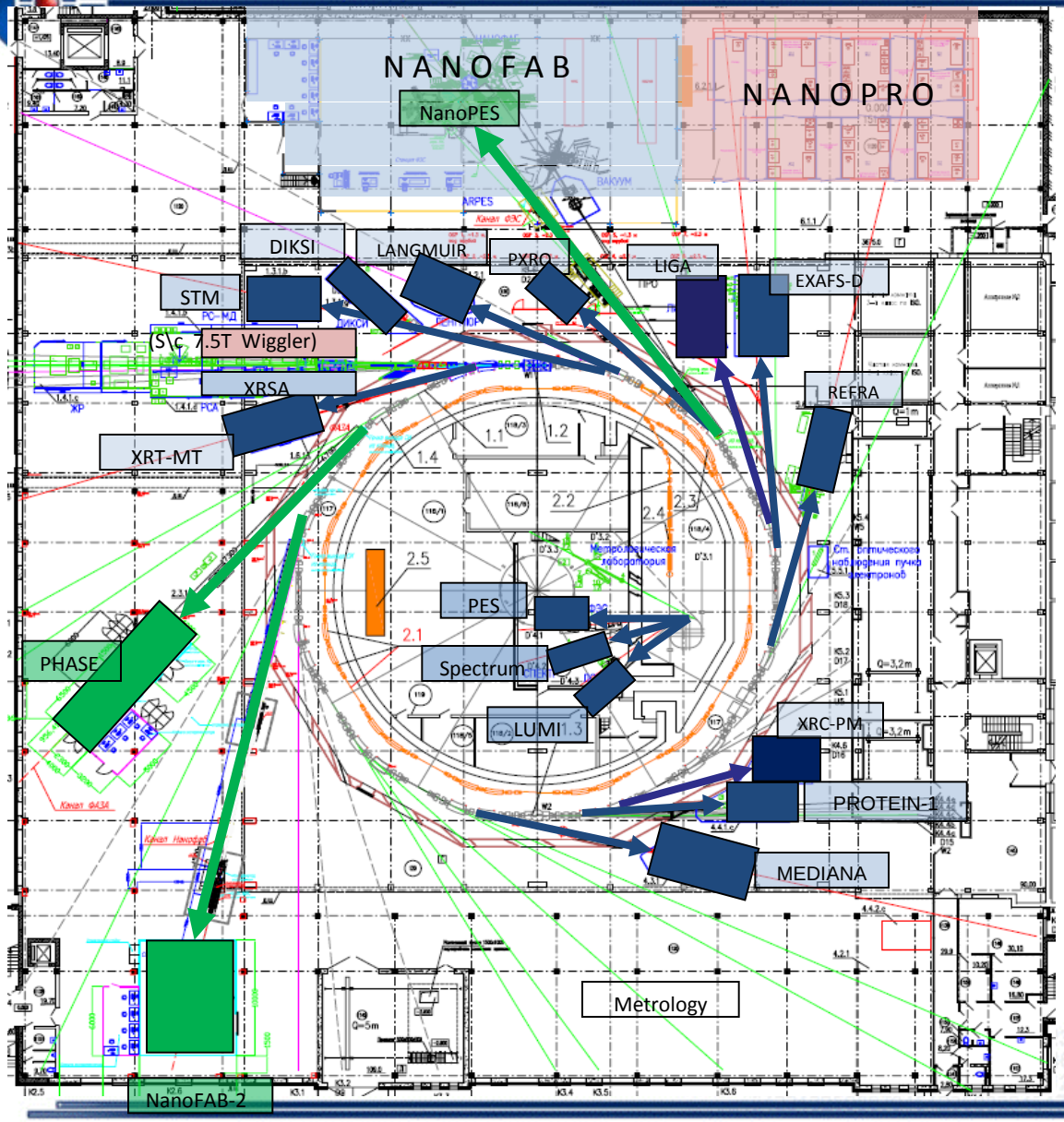
Superconducting wire Nb3Sn for ITER





200 μm

Upgrade programm, Phase-I:
3 new beamlines

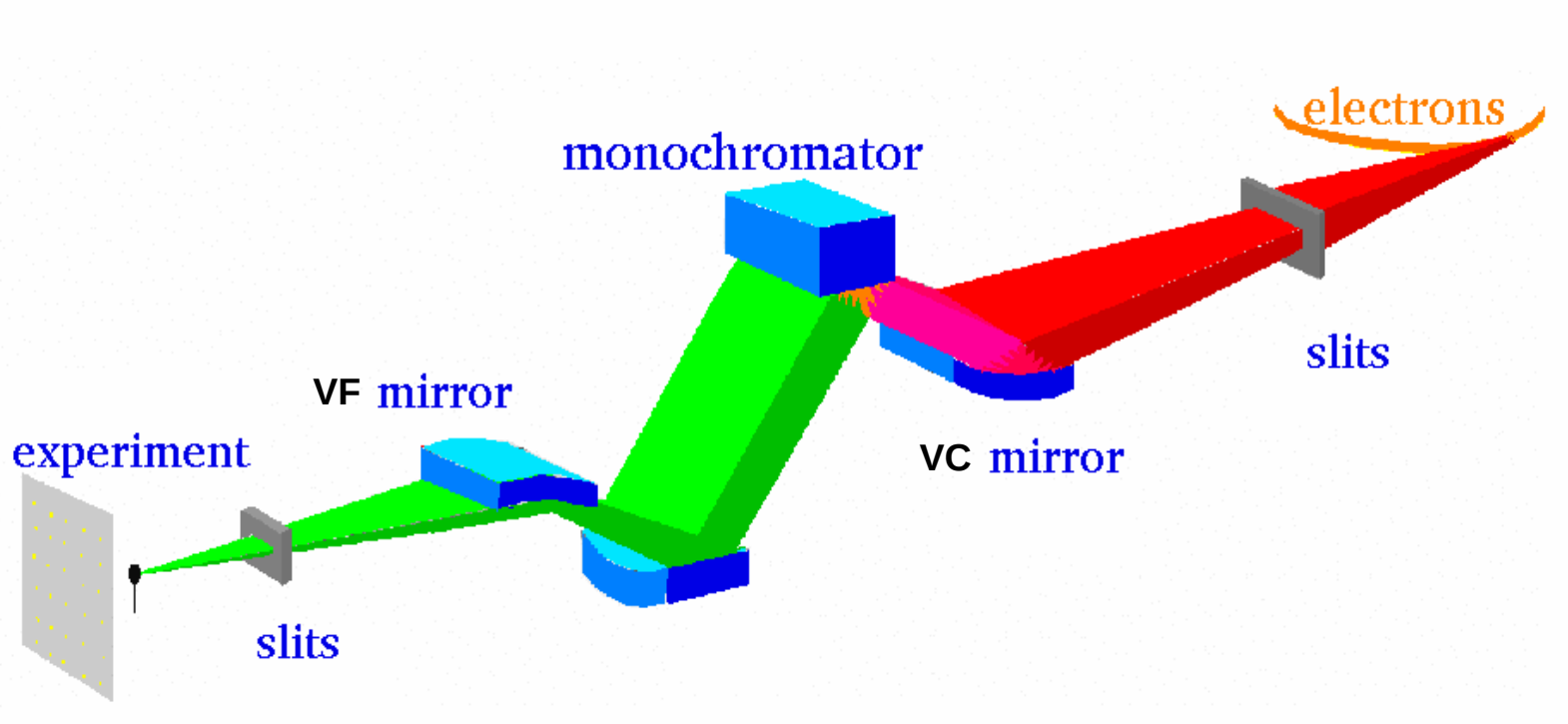


Beamlines:

Operational

Constructed in Upgrade P-1

New PHASE beamline

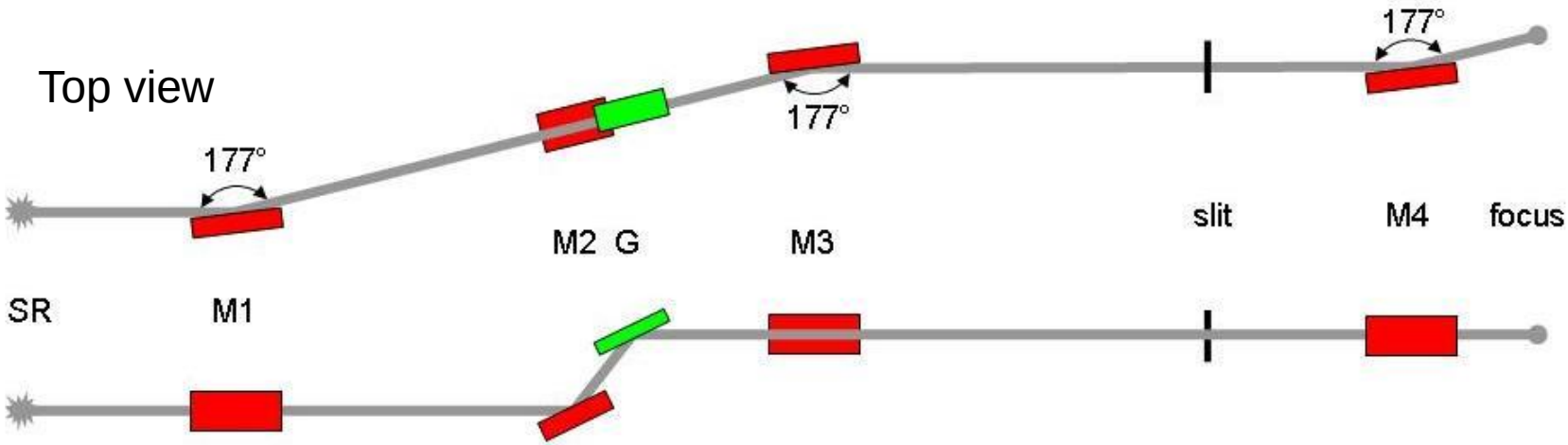


6+2 –Gonio **HUBER** (mod 5021)

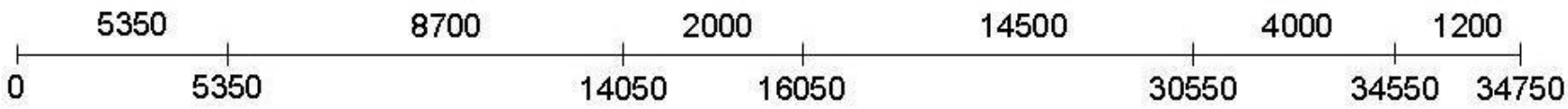
Axis name	Angular resolution (arc sec)
Omega (horiz)	0.1
2Theta (horiz.)	0.36
Chi	0.72
Phi	0.72
Omega (vert)	0.36
2Theta (vert)	0.36
Omega analyser	0.36
2Theta-analyser	1.44

Experimental hutch – November 2012

The ARPES beamline – optics



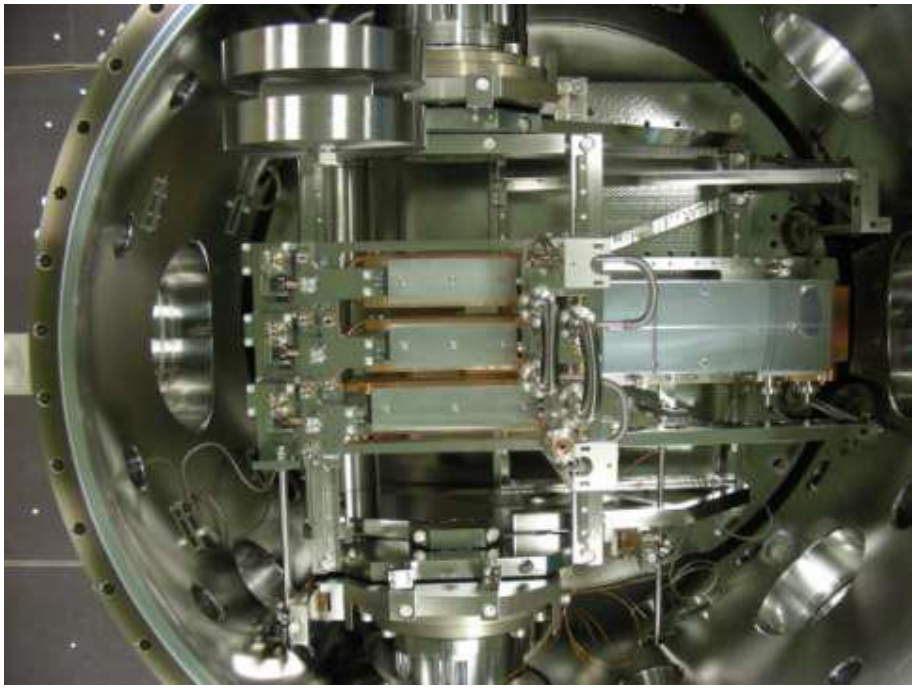
Distance between elements



Distance from the source

The Mono for ARPES

Inside the mono



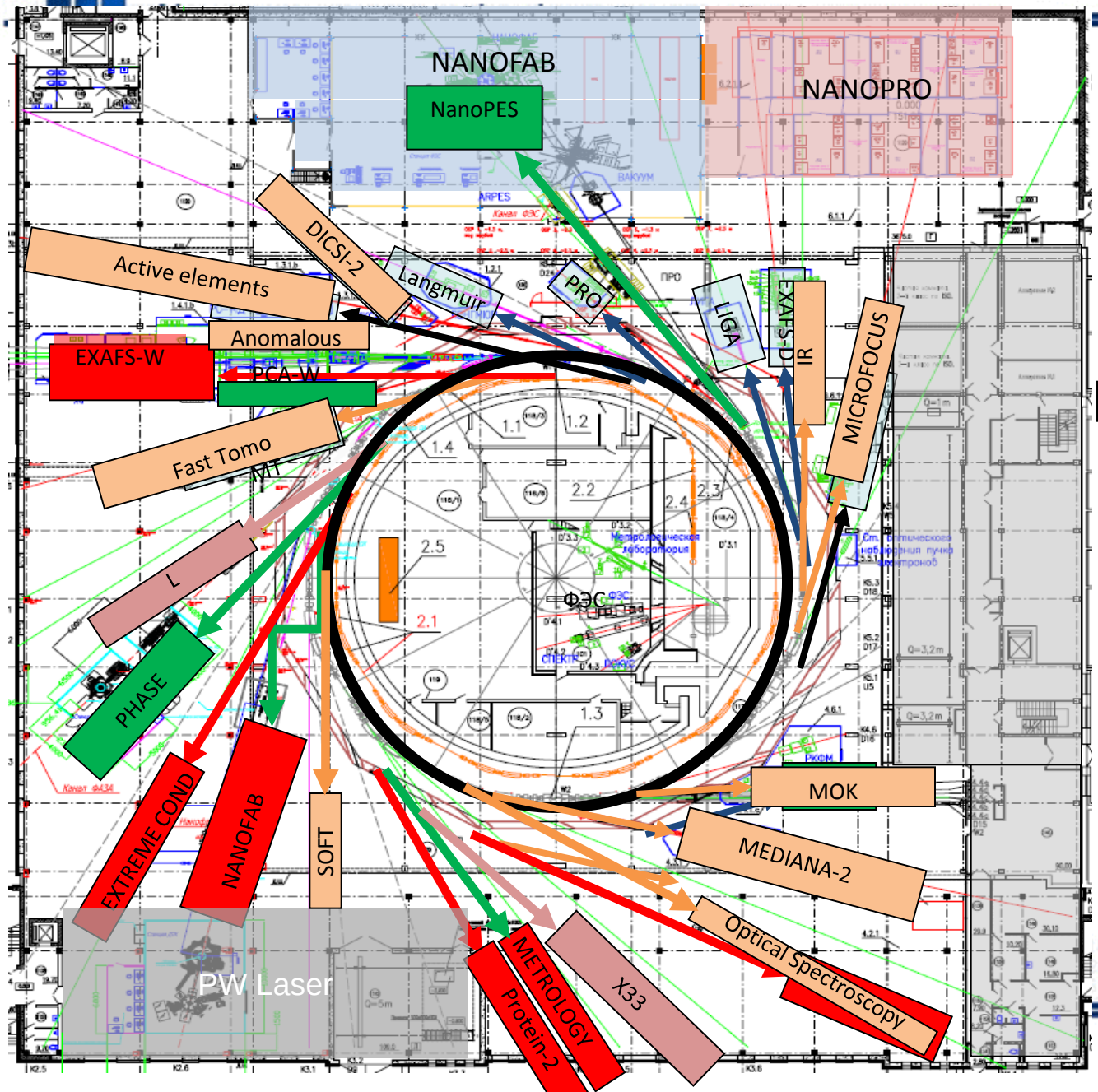
Mirror and 3 gratings (water cooled)

ARPES spectrometer

Upgrade programm, Phase-II: 10 new beamlines

Upgrade Plans

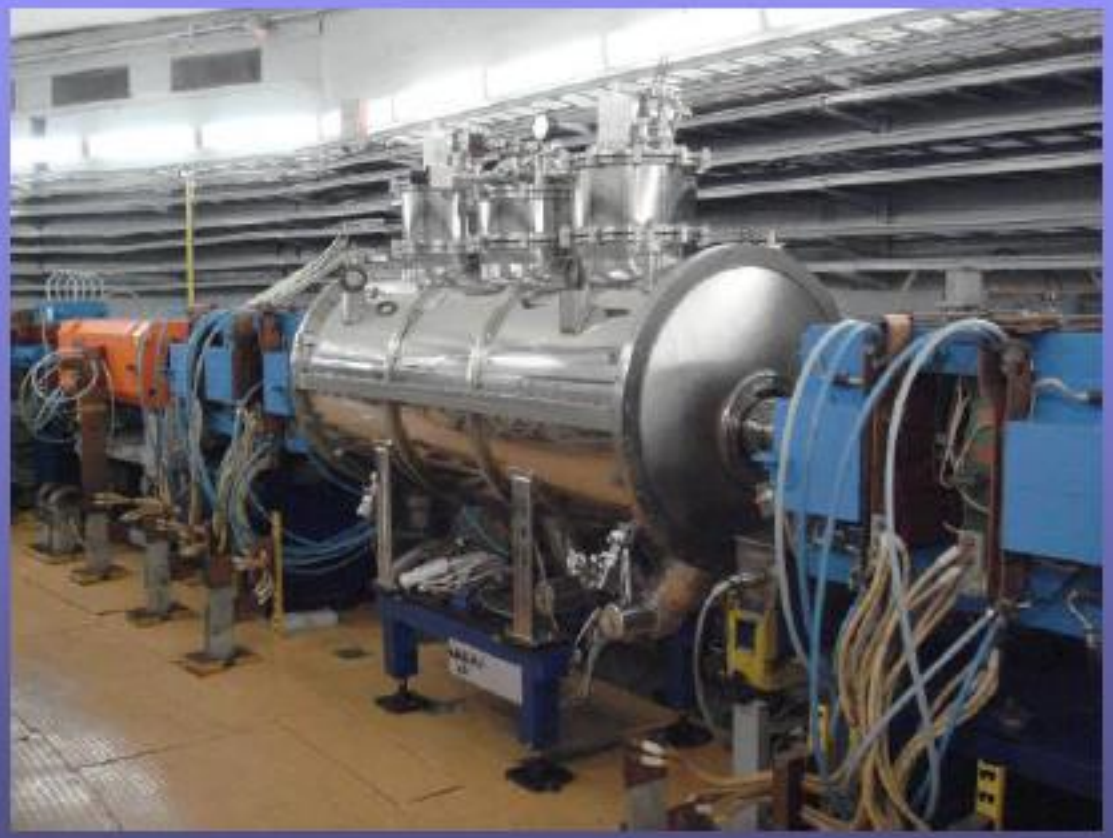
National Research Center "Kurchatov Institute"



New beamlines, next upgrade phase

The machine modernization

7.5 T SC Wiggler



Dispersion free straight section of Siberia-2

MPSCW: NbTi coils

E=2.5 GeV, I=0.1-0.3 A

B= 3 - 7.5 T, Npoles=19+2

λ_{wig} = 164 mm

Eph crit. = 31.2 keV

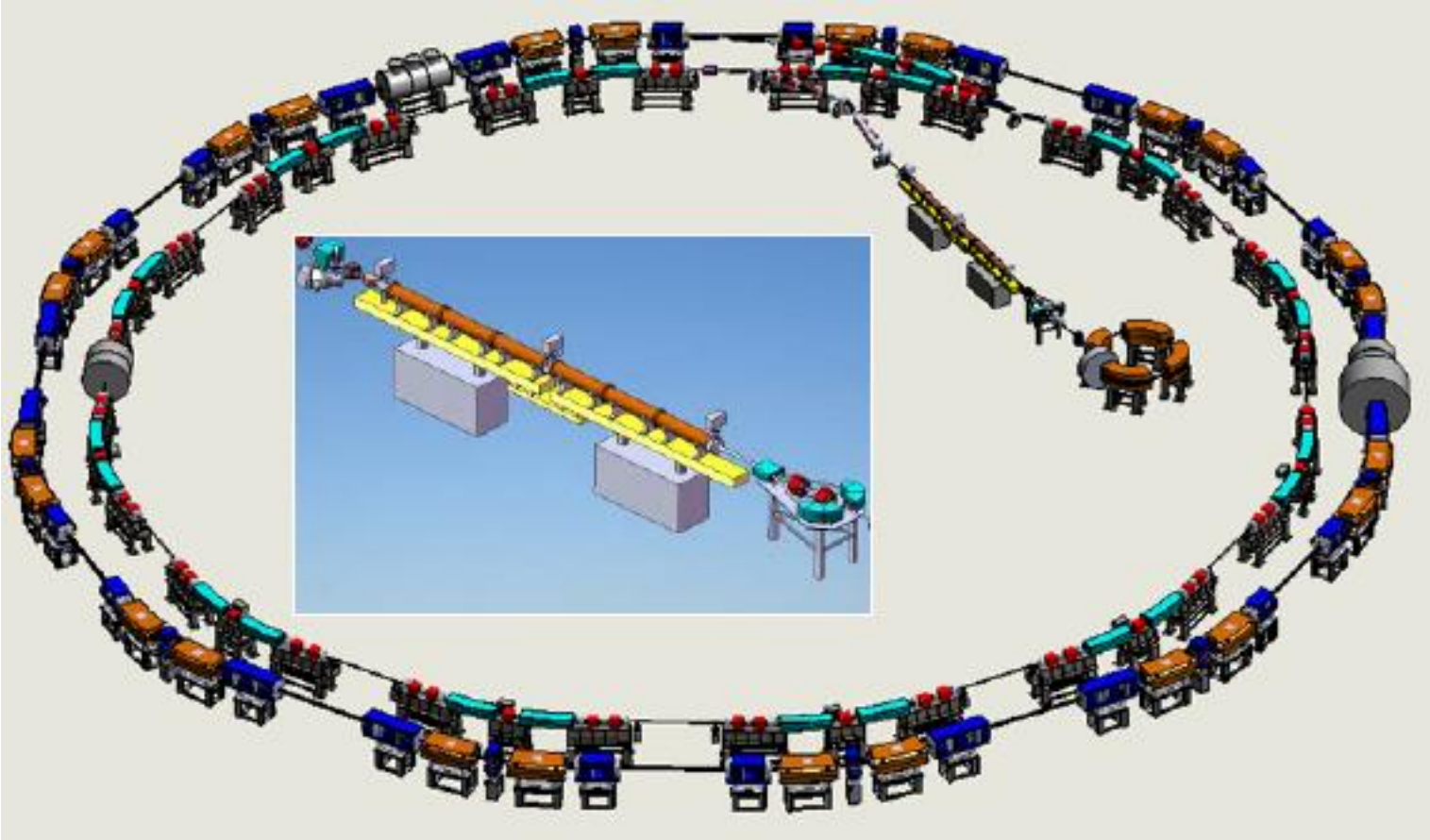
Flux = (10^{14}-10^{12}) ph/s/0.1%BW

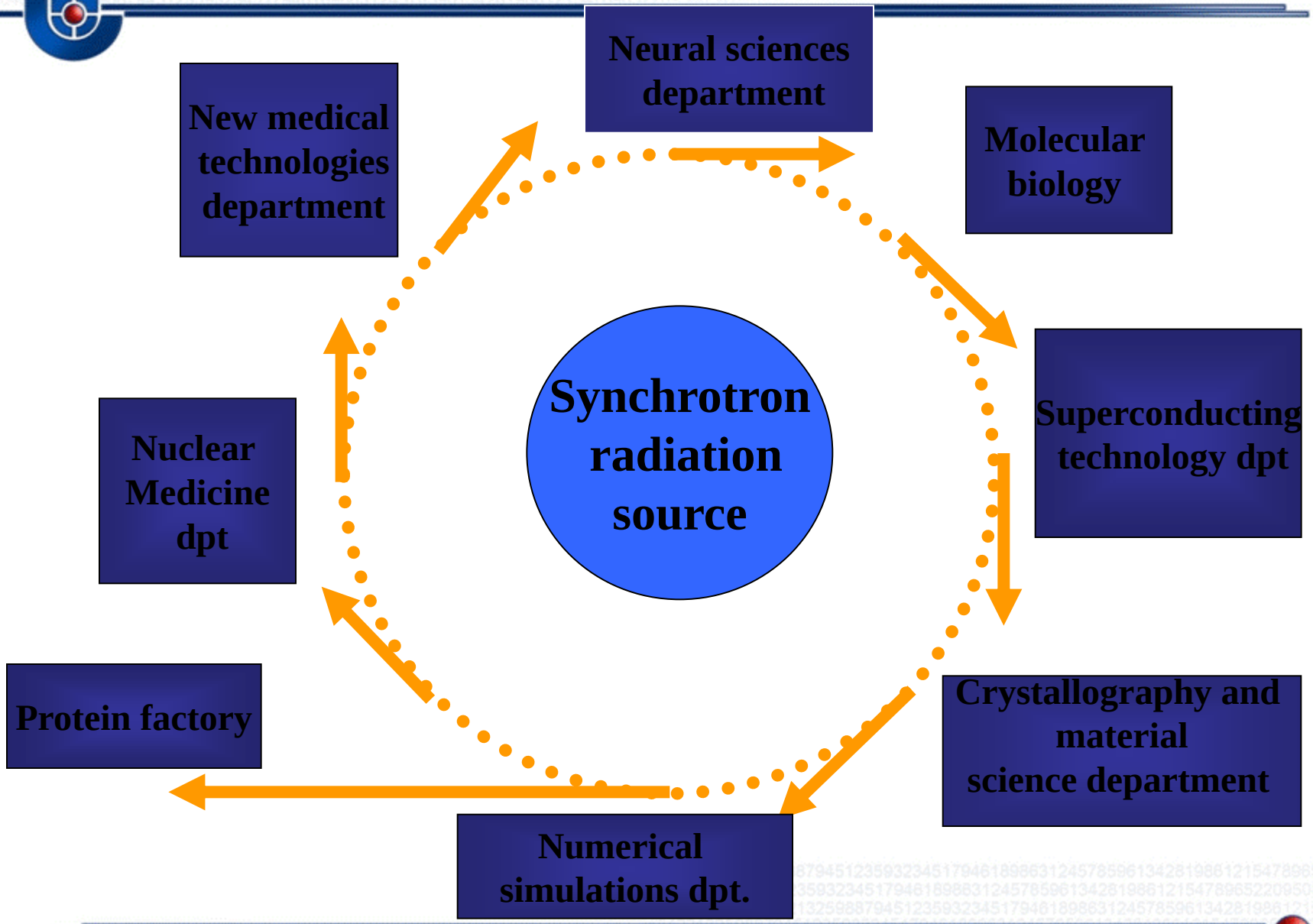
Eph = 5 - 200 keV .

Θx max = $\pm$ 23.5 mrad

Ptot (100 mA) = 36.5 kW

New booster inside the existing ring



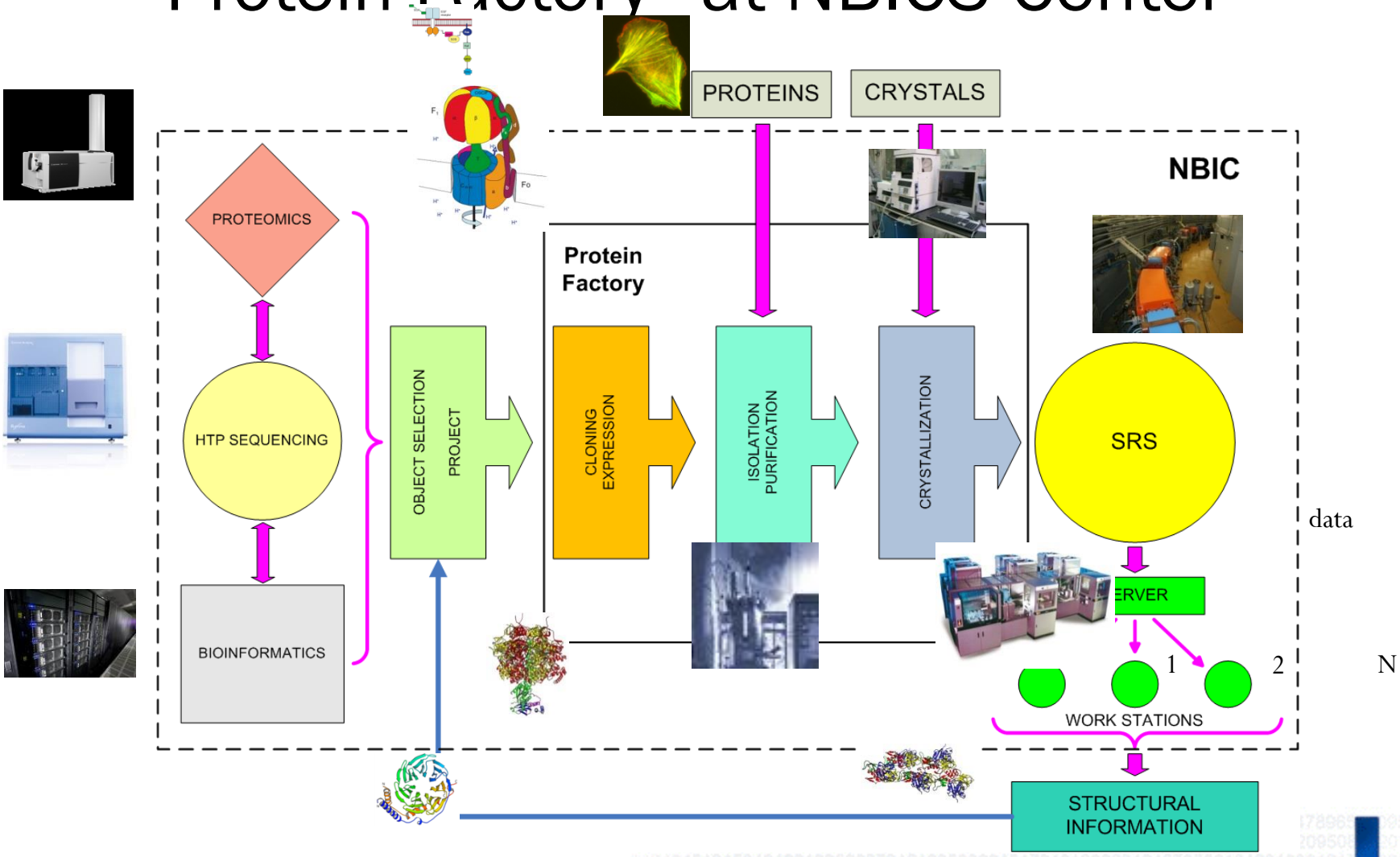

Neural sciences department
Molecular biology
Superconducting technology dpt
Crystallography and material science department
Numerical simulations dpt.
Protein factory
Nuclear Medicine dpt
New medical technologies department
Synchrotron radiation source

Facilities around synchrotron

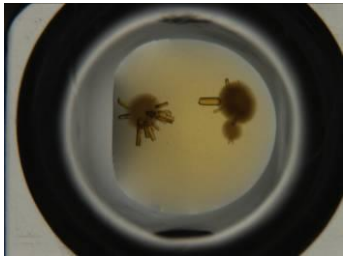
RESEARCH INFRASTRUCTURE

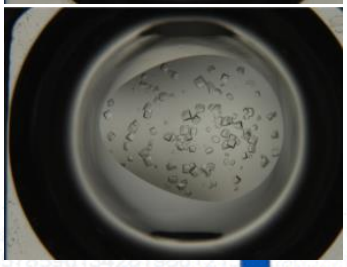
- **Kurchatov Synchrotron Radiation Center**
- **Nuclear Research Reactor IR–8**
- **Data Processing Center**
- **Nanobiological Science&Technology Center**

"Protein Factory" at NBICS-Center

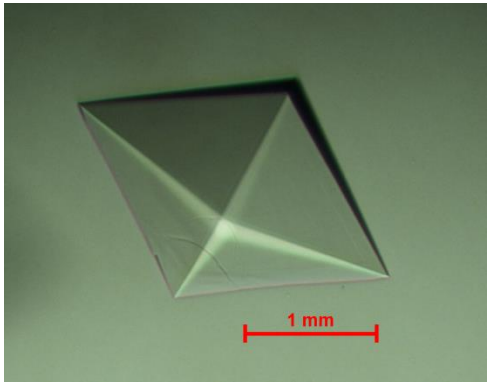


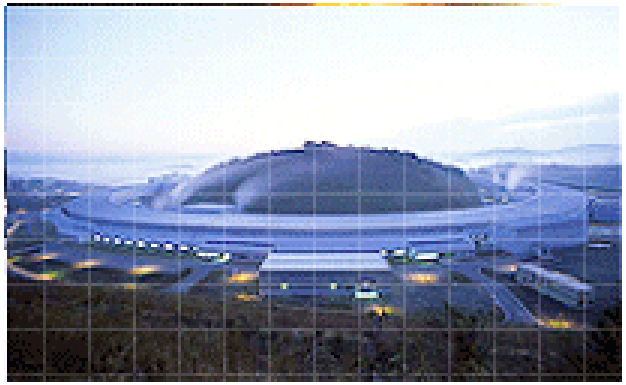
Automated crystallization system





JOINT RUSSIAN-JAPANESE PROJECT



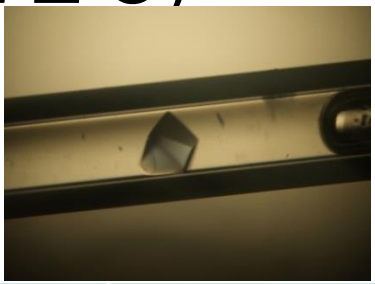


Goal

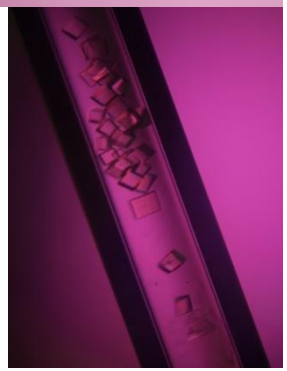
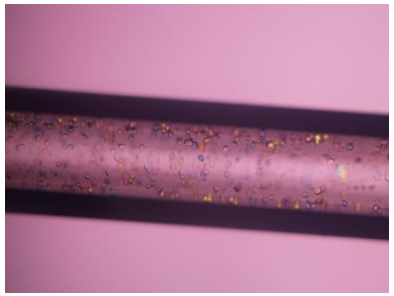
Use of microgravity crystallization for growing high quality protein crystals

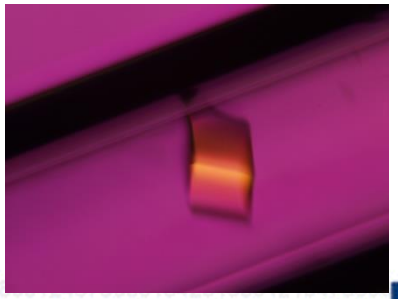
INTERMEDIATE RESULTS (JAXA#1-5)



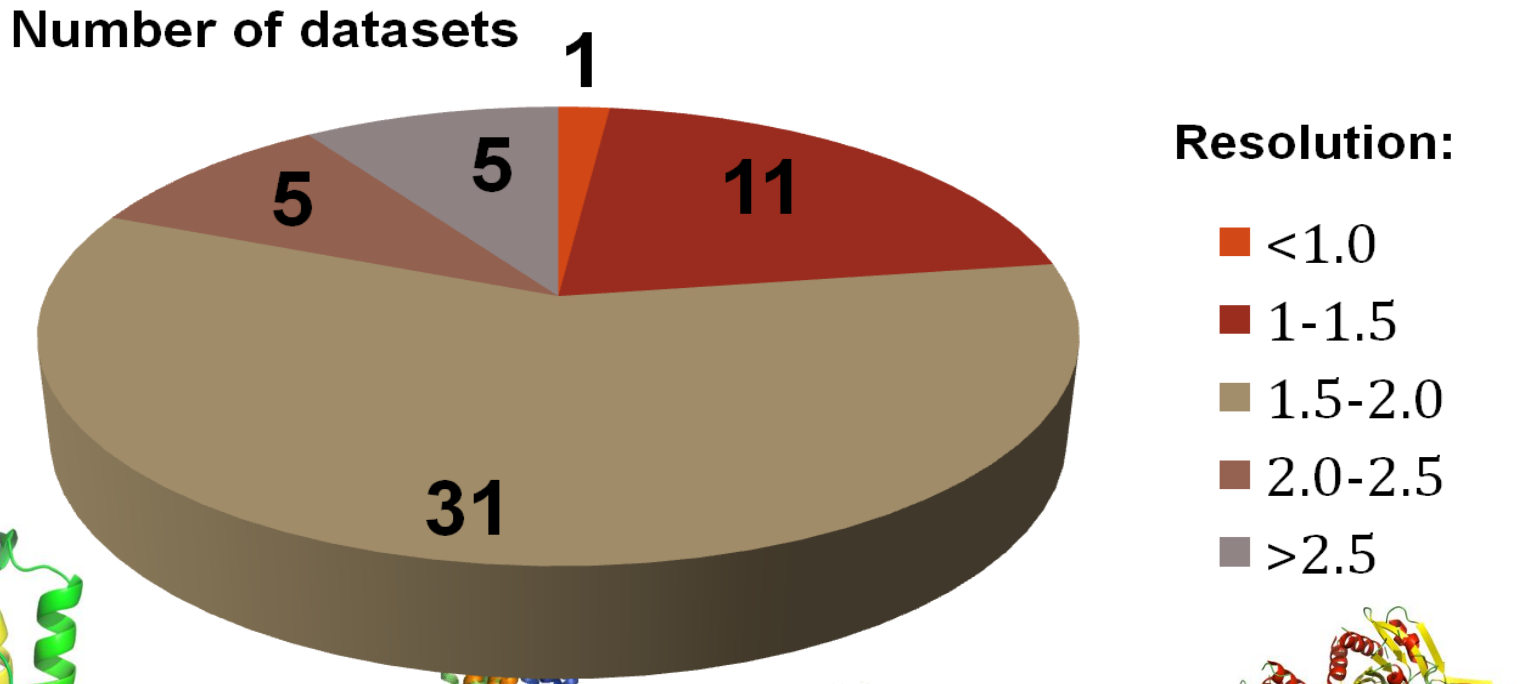


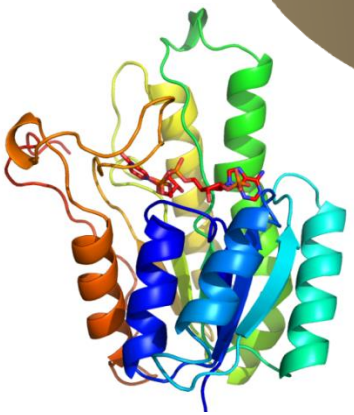
Total proteins	**29**
Crystallized (diffracting)	**16**
Unique datasets	**51**
Refined	**31**

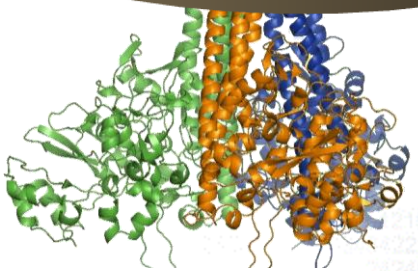



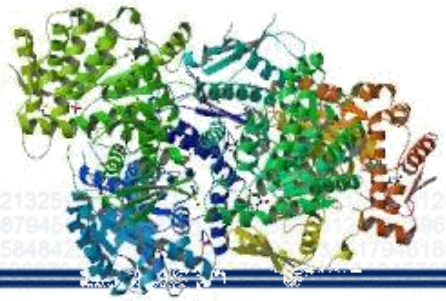



INTERMEDIATE RESULTS (JAXA#1-5)





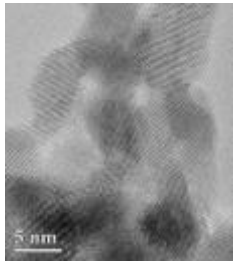


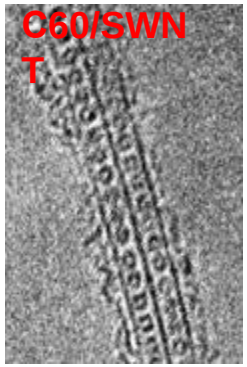


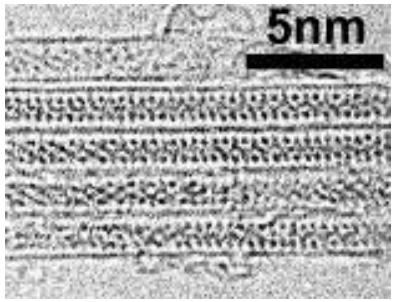
NANOBIOTECHNOLOGICAL CENTER

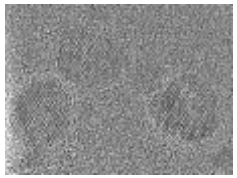
Proteomic lab

ELECTRON MICROSCOPY LAB

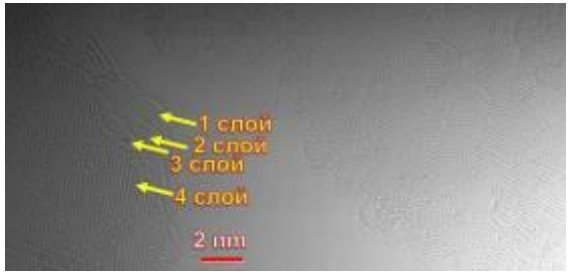




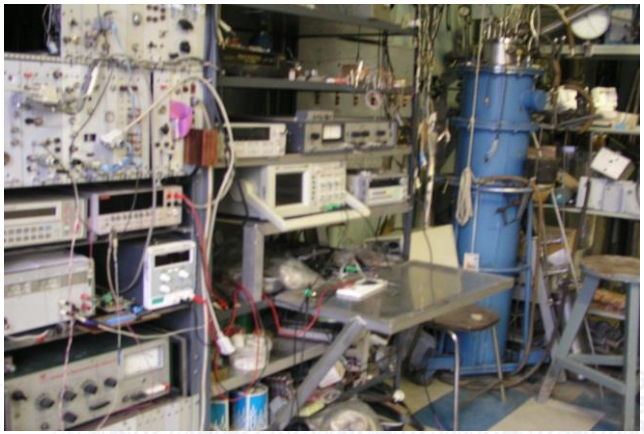




CdS



Technical superconductivity department



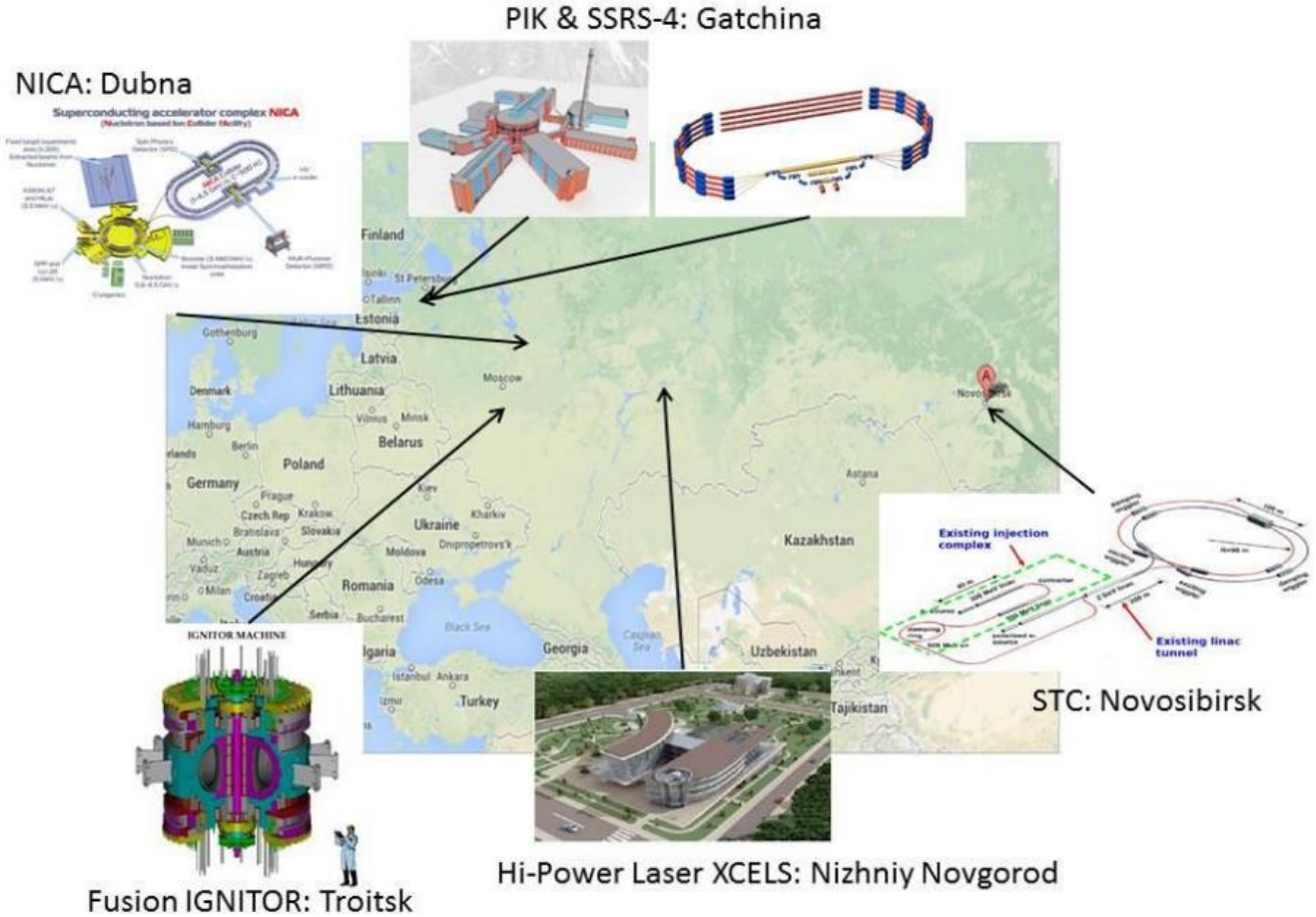
And many others…

CREMLIN Project

Connecting Russian and European Measures for Large-scale Research Infrastructures (CREMLIN)

> Submitted: 02.09.2014
> 28.1.2015: green light by European Commission; excellent marks
> Grant Agreement signed April 2015
> CSA-Project (Cooperation and Support Action) under Horizon 2020
> Duration: 3 years
> Coordinator: DESY; Russian key partner: NRC “Kurchatov Institute”
> Budget: ~1.7M€
> Project (“action”) start: 1 September 2015
> Launch & Opening Conference: 7 – 8 October 2015, Moscow

CREMLIN in the map



CREMLIN

CREMLIN targets at all 6 (5) Russian megascience projects:

- Scientific and Research Reactor Complex PIK at PNPI Gatchina
- Nuclotron-based Ion Collider Facility NICA at JINR Dubna
- Fourth Generation Special-purpose Synchrotron Radiation Source SSRS-4,
NRC “Kurchatov Institute” Moscow
- Exawatt Center for Extreme Light Studies XCELS, IAP Nizhniy Novgorod
- Super Tau-Charm Factory STC, BINP Novosibirsk
- (IGNITOR Tokamak Fusion Reactor, initiated by NRC Kurchatov Institute)

Thank you for your attention and welcome to NRC Kurchatov institute