International Conference on Condensed Matter Research at the IBR-2
October 11-15, 2015, Dubna

RUSSIA NEUTRON LANDSCAPE

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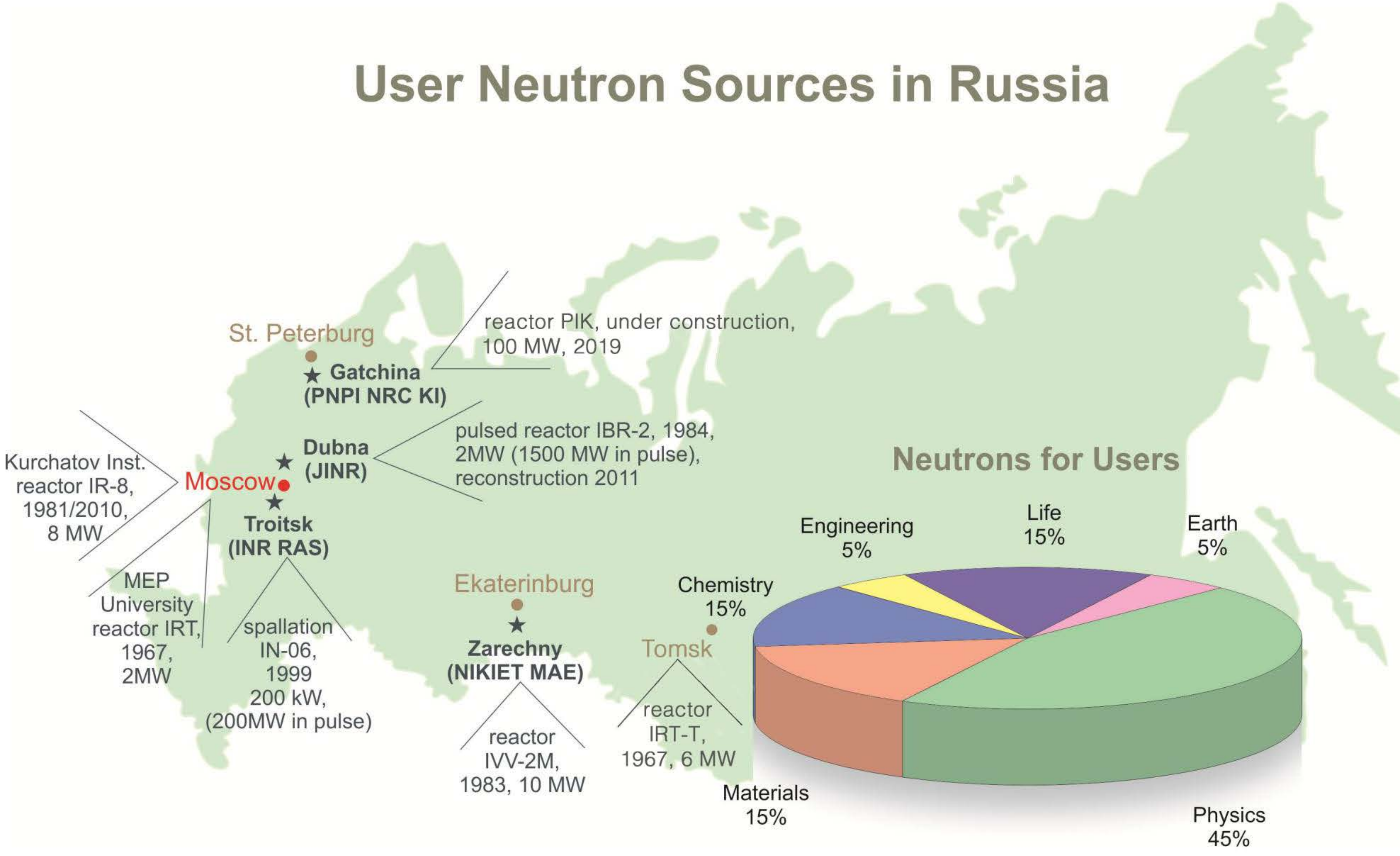
National Research Center “Kurchatov Institute” (PNPI, Gatchina)
Joint Institute for Nuclear Research (JINR, Dubna)

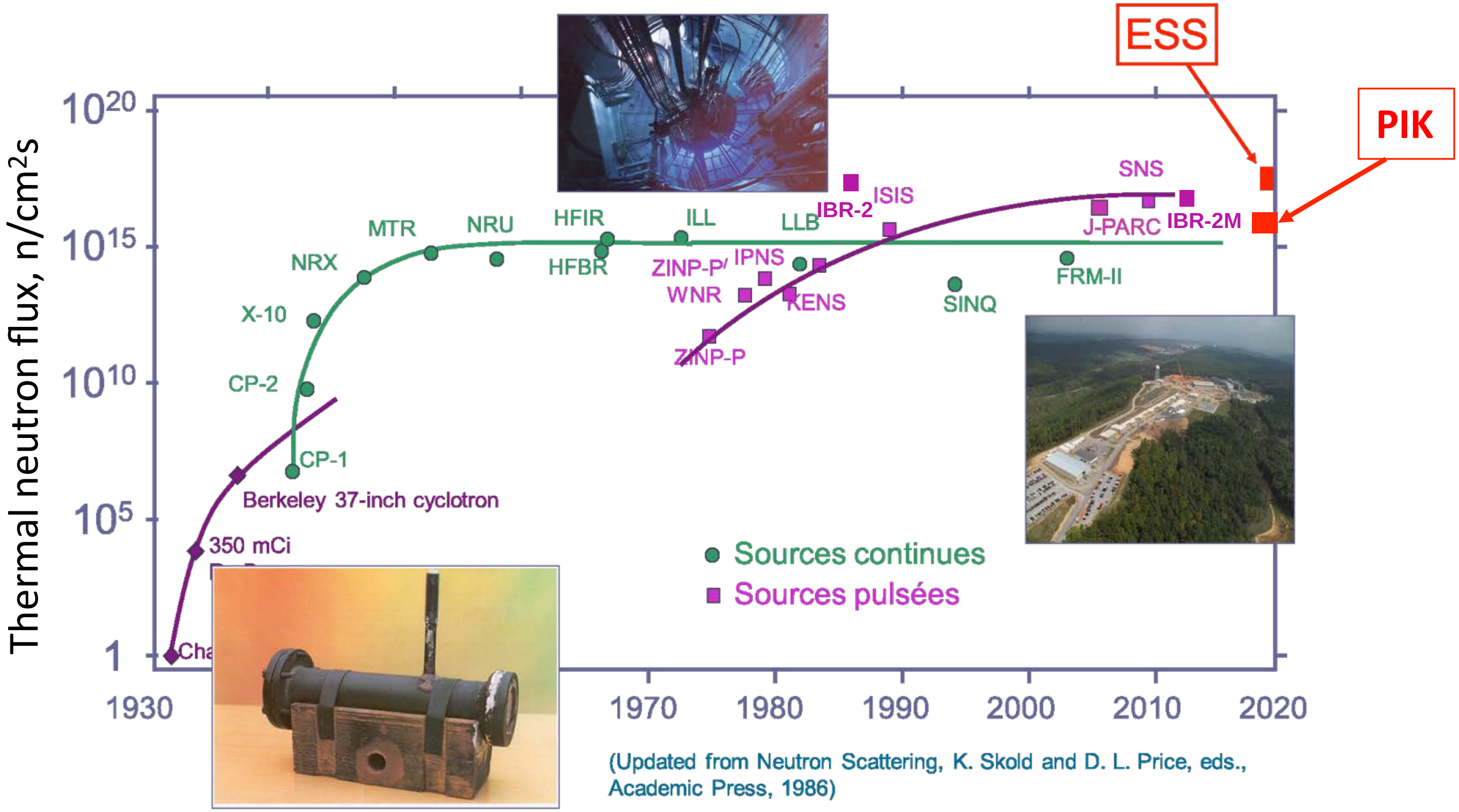
- What do we have? (present status)
- Why do we need more neutrons? (neutrons in modern sciences)
- What will we have? (new projects)

What do we have?

- present status


User Neutron Sources in Russia
St. Peterburg
Gatchina
(PNPI NRC KI)
reactor PIK, under construction,
100 MW, 2019
Dubna
(JINR)
pulsed reactor IBR-2, 1984,
2MW (1500 MW in pulse),
reconstruction 2011
Kurchatov Inst.
reactor IR-8,
1981/2010,
8 MW
Moscow
Troitsk
(INR RAS)
MEP
University
reactor IRT,
1967,
2MW
spallation
IN-06,
1999
200 kW,
(200MW in pulse)
Ekaterinburg
Zarechny
(NIKIET MAE)
reactor
IVV-2M,
1983, 10 MW
Tomsk
reactor
IRT-T,
1967, 6 MW
Neutrons for Users
Engineering
5%
Life
15%
Earth
5%
Chemistry
15%
Materials
15%
Physics
45%

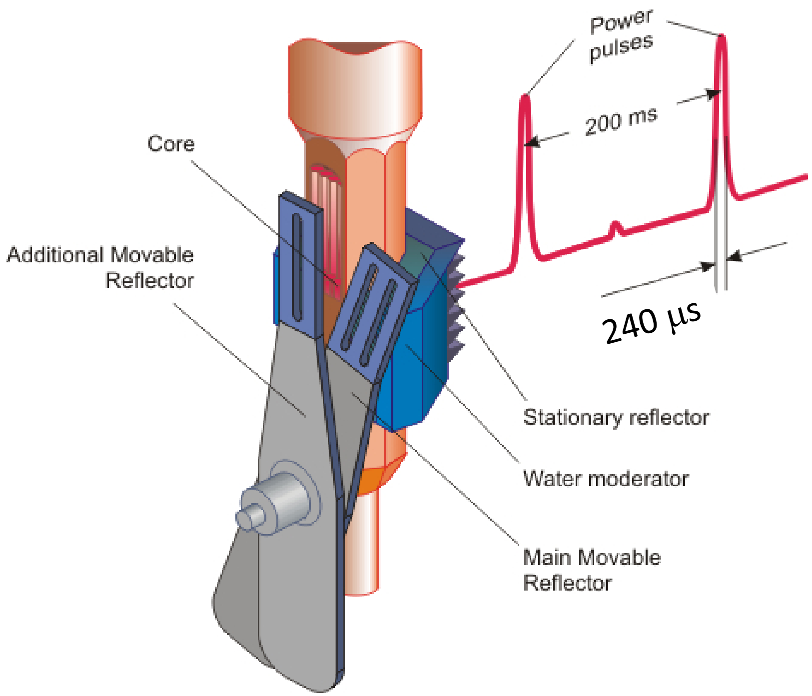
Neutron Sources: fluxes



But the real gain comes from the technical progresses on the neutron instruments!

A. Ioffe

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

Strategy Paper of the NRC "Kurchatov Institute" and the Joint Institute for Nuclear Research

Steady state

WWR-M (NRC KI, Gatchina) : shutdown mode, 2016

IR-8 (NRC KI, Moscow) : 2007 ÷ 2017 upgrade, 2040

PIK (NRC KI, Gatchina) : 2019 ÷ 2049

Pulsed sources

GNEIS (NRC KI, Gatchina) : 1971, proton synchrocyclotron, 1GeV

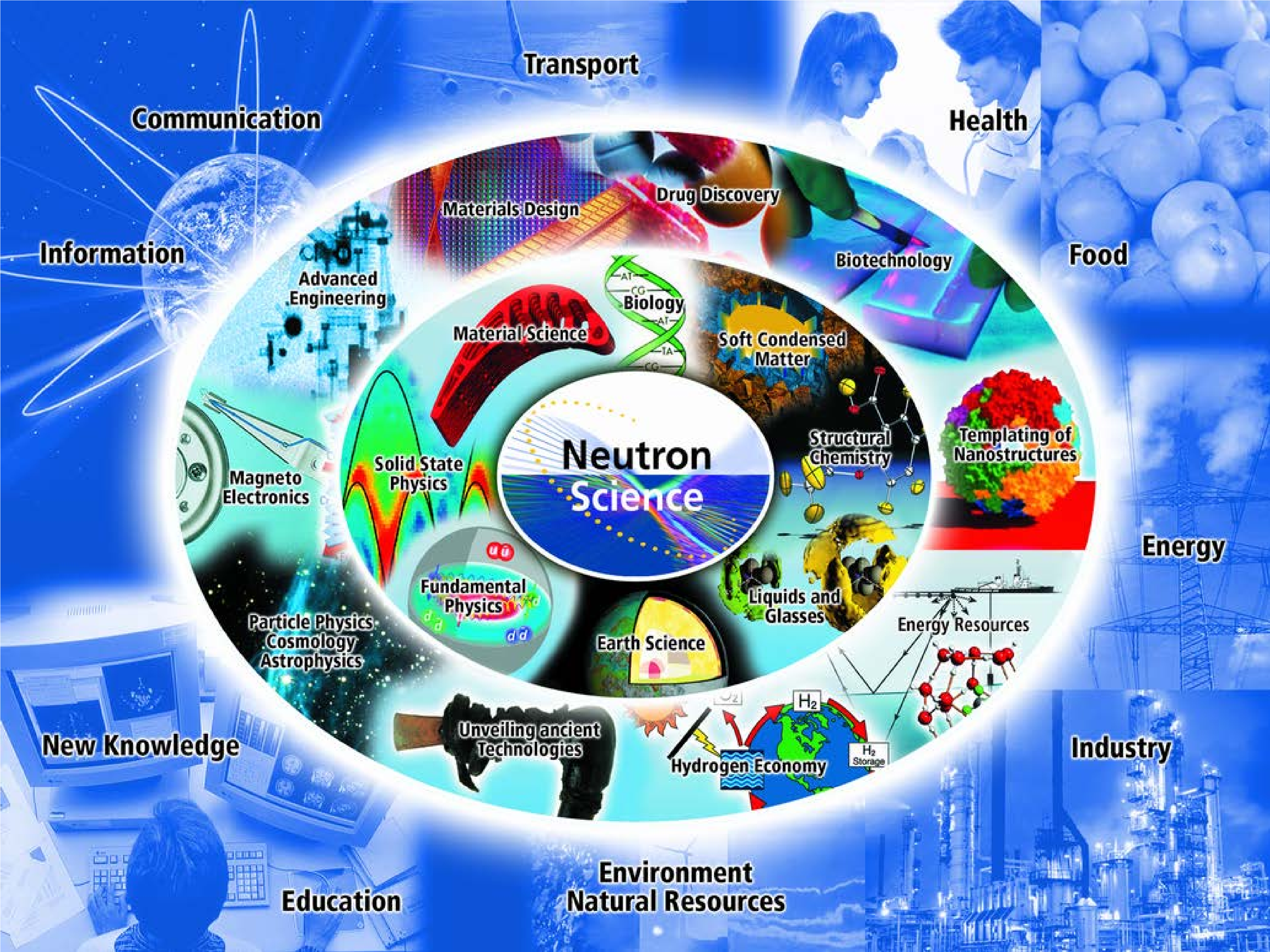
IREN (JINR, Dubna) : 2010 ÷ 2045

IBR-2 (JINR, Dubna) : 2012 ÷ 2037

DANS (JINR, Dubna) : proposal (proton linac, multiplaying target) after 2037

Why do we need more neutrons?

- neutrons in modern sciences

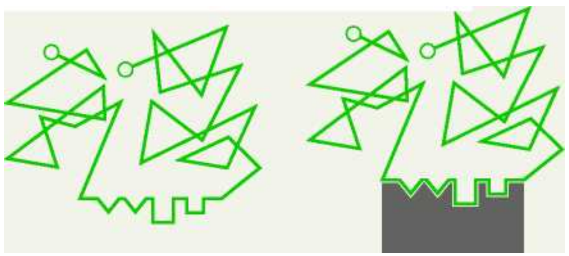


Transport
Communication
Health
Food
Information
Materials Design
Drug Discovery
Biotechnology
Advanced Engineering
Biology
Material Science
Soft Condensed Matter
Neutron Science
Structural Chemistry
Templating of Nanostructures
Solid State Physics
Magneto Electronics
Energy
Fundamental Physics
Liquids and Glasses
Energy Resources
Particle Physics Cosmology Astrophysics
Earth Science
Unveiling ancient Technologies
Hydrogen Economy
New Knowledge
Industry
Education
Environment
Natural Resources

STRUCTURAL BIOLOGY: breaking the protein rules

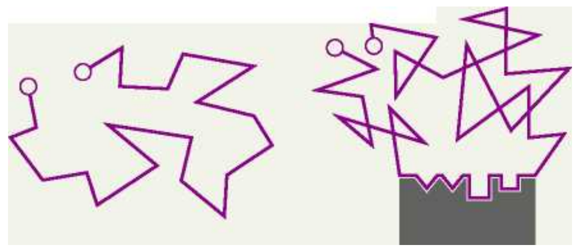
A central tenet in molecular biology states that the function of a protein depends on its fully folded three-dimensional structure. In the new view, protein segments can function when transiently or durably disordered.

LOCK AND KEY



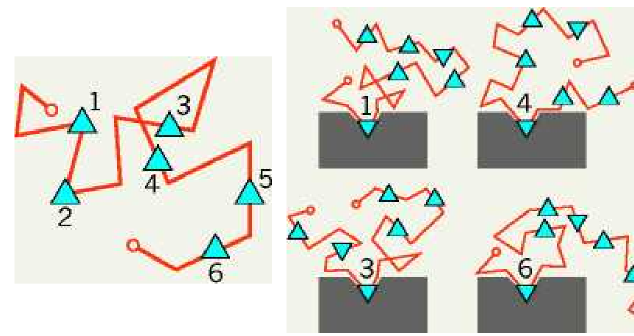
In the conventional view, an enzyme folds up immediately into a unique and stable 3D shape, the key (left). Its shape perfectly matches and allows it to bind its substrate, the lock (right).

FOLD AS YOU BIND



A disordered part of the gene-regulatory protein CREB (left) uses the lock to mould itself into the shape of the key when the two meet (right), rather than folding beforehand.

SHAPE SHIFTING

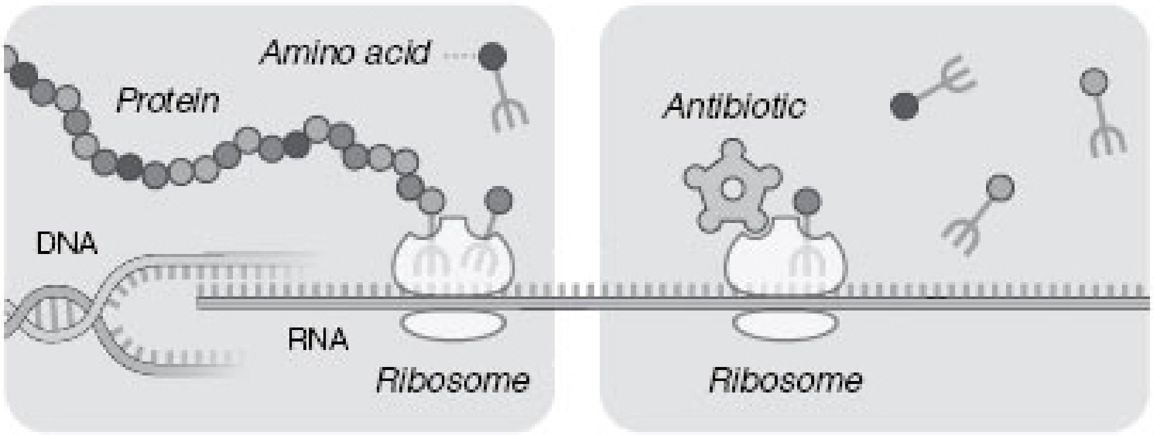


The signalling protein Sic1 remains disordered in its bound state, and each of six phosphate groups occupies the binding site in turn. The protein is a mix of dierent conformations shifting around in constant dynamic equilibrium.

«… who compares the excitement now to that surrounding the first crystal protein structures in the 1950s. "Every new case is fascinating at the moment," he says.»

T. Chouard Nature (2011) V. 471

From the structure and functioning of ribosomes to novel antibiotics

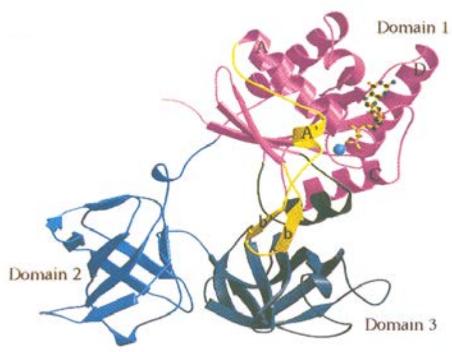


A simplified scheme of the functioning of ribosomes (left) and its blocking by antibiotics (right). The synthesis of the information RNA takes place on the DNA template. Two ribosomal subunits (Ribosome) subsequently attach to RNA, and the protein synthesis starts (Protein). Each amino acid in the composition of the protein chain is delivered to the ribosome by the transfer RNA (shown schematically as a fork). Some antibiotics are capable to bind bacterial ribosomes and stop protein synthesis, thus leading to the death of bacterial cells.

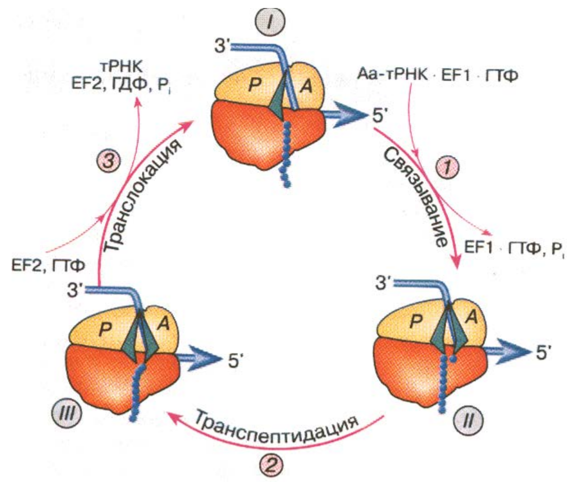
T. Steitz Nobel prize lecture, 2009

Protein eEF1A – elongation factor of translation

The main role of elongation factors: to increase the rate of elongation by several orders of magnitude and to facilitate accurate fixing of complexes.



Structure of elongation factor



Elementary elongation cycle of the ribosome, when one triplet (codon) of mRNA is read and one amino acid is added to the growing polypeptide

An example of an unstructured protein. Neutron scattering experiments with isotopic substitution and polarization analysis revealed that the eEF1A protein has no fixed rigid structure in solution, and its conformation is more expanded and disordered than its prokaryotic counterparts.

A fourth native state of eukaryotic factors – the state with high cross-domain mobility – was proposed.

I.Serdyuk, V.Aksenov et al. J.Mol.Biol. 292 (1999) 633; T.Budkevich, I.Serdyuk, V.Aksenov et al. Biochemistry, 41 (2002) 15342

Comparison with ILL and FRM-II

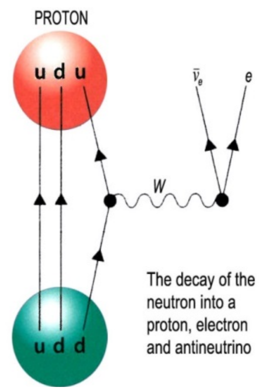
	PIK	ILL	FRM-II	HFIR	SNS	J-Park	ISIS
Diffraction	7	13	9	6	6	7	12
SANS	6	5	6	2	2	1	4
Spectroscopy	5	17+3	10	4	9	4	8
Reflectometry	4	3	2	-	2	2	5
Fund. Physics	9	7	4	-	1	3	-
Sum	32	45+3	31	12	20	17	29

Neutrons and New Physics

Early Universe : τ_n

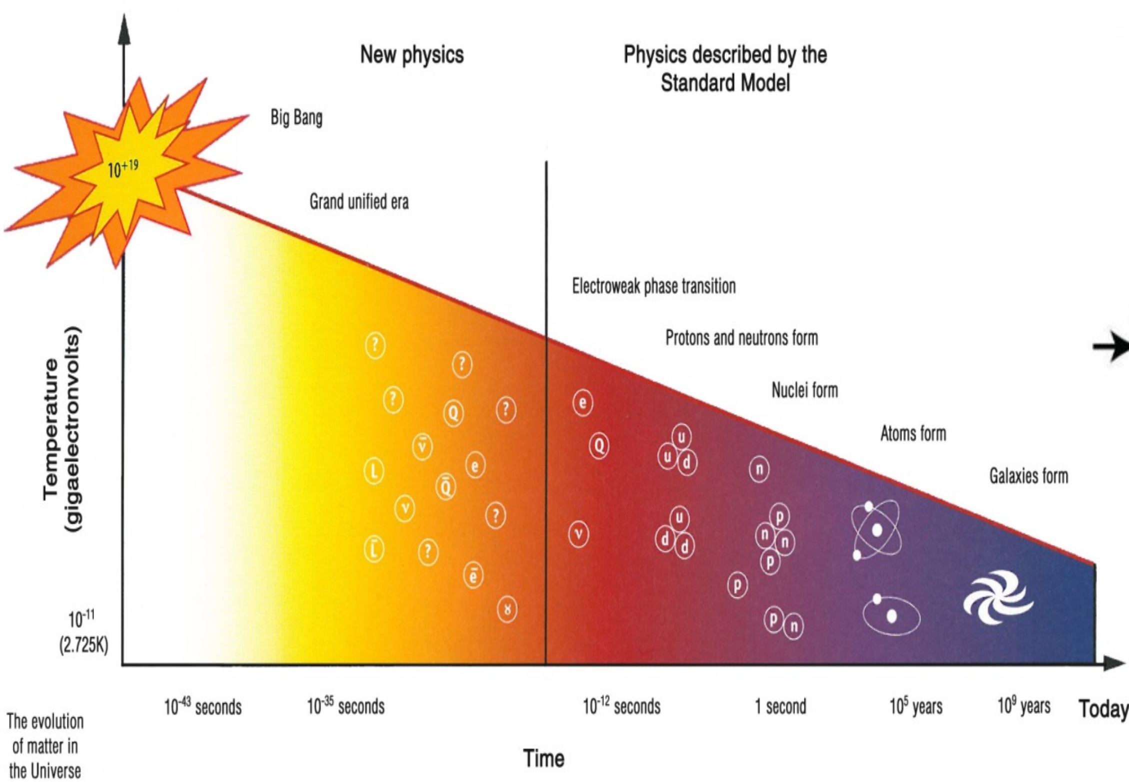
Barion asymmetry : EDM

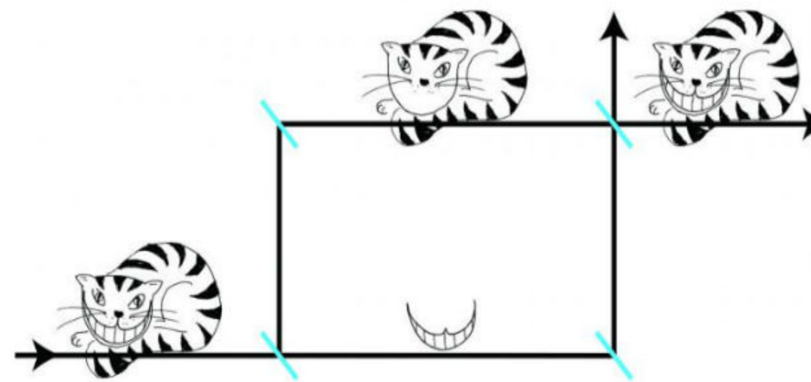
Left-right symmetry : (n, α)



Dark energy
Dark matter } UCN gravity resonance Spectroscopy in ILL

Neutrino Physics





UCN: **Quantum mechanics (Schrödinger and Cheshire cats)**
ILL experiments 2014

Understanding of the nucleus

Nuclear Structure
(nuclear models)

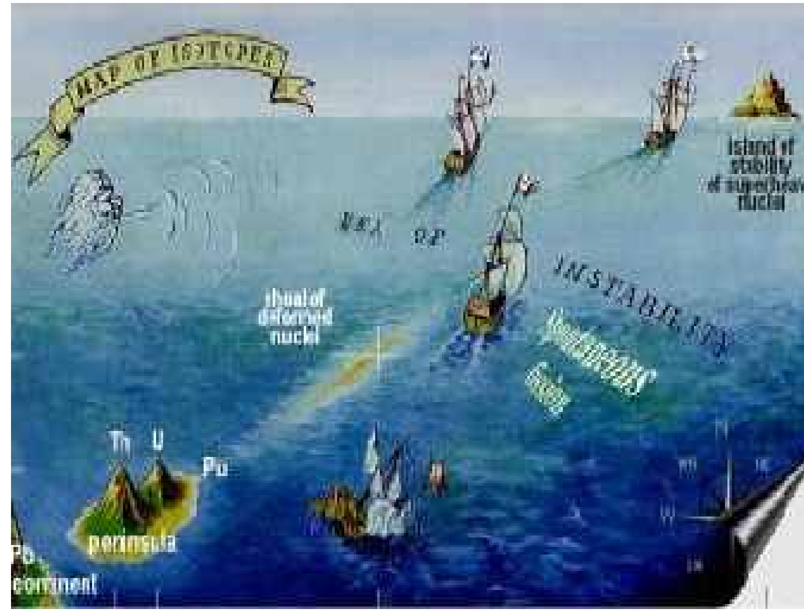
Probing exotic
(n-rich) nucleus

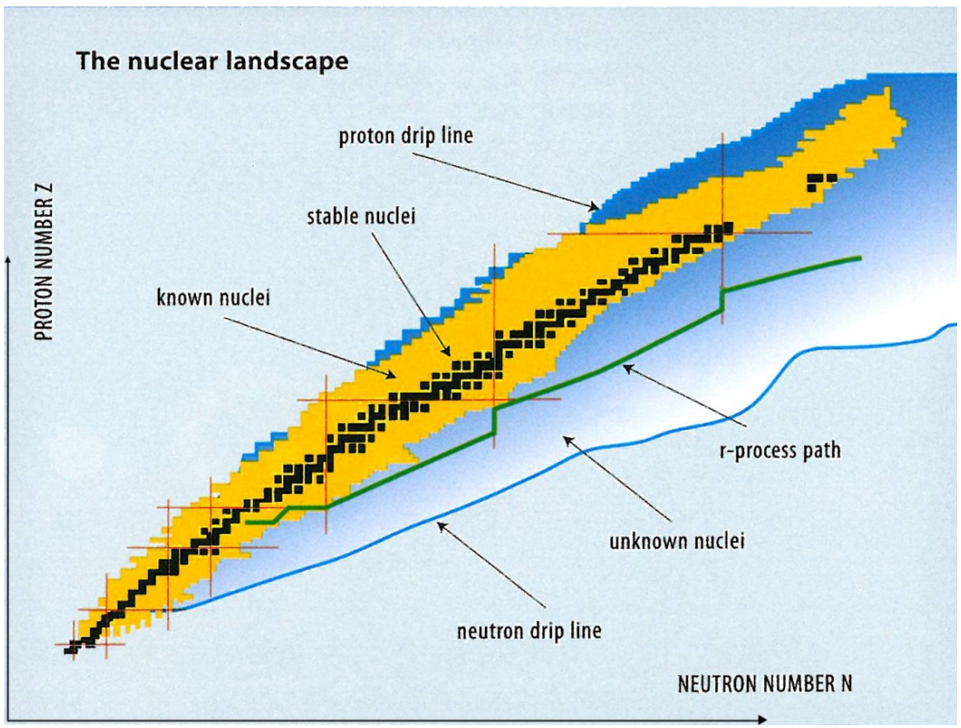
Phase Transitions
in nuclei

Fission Physics

Nuclear Data

Superheavy elements
Gatchina-Dubna





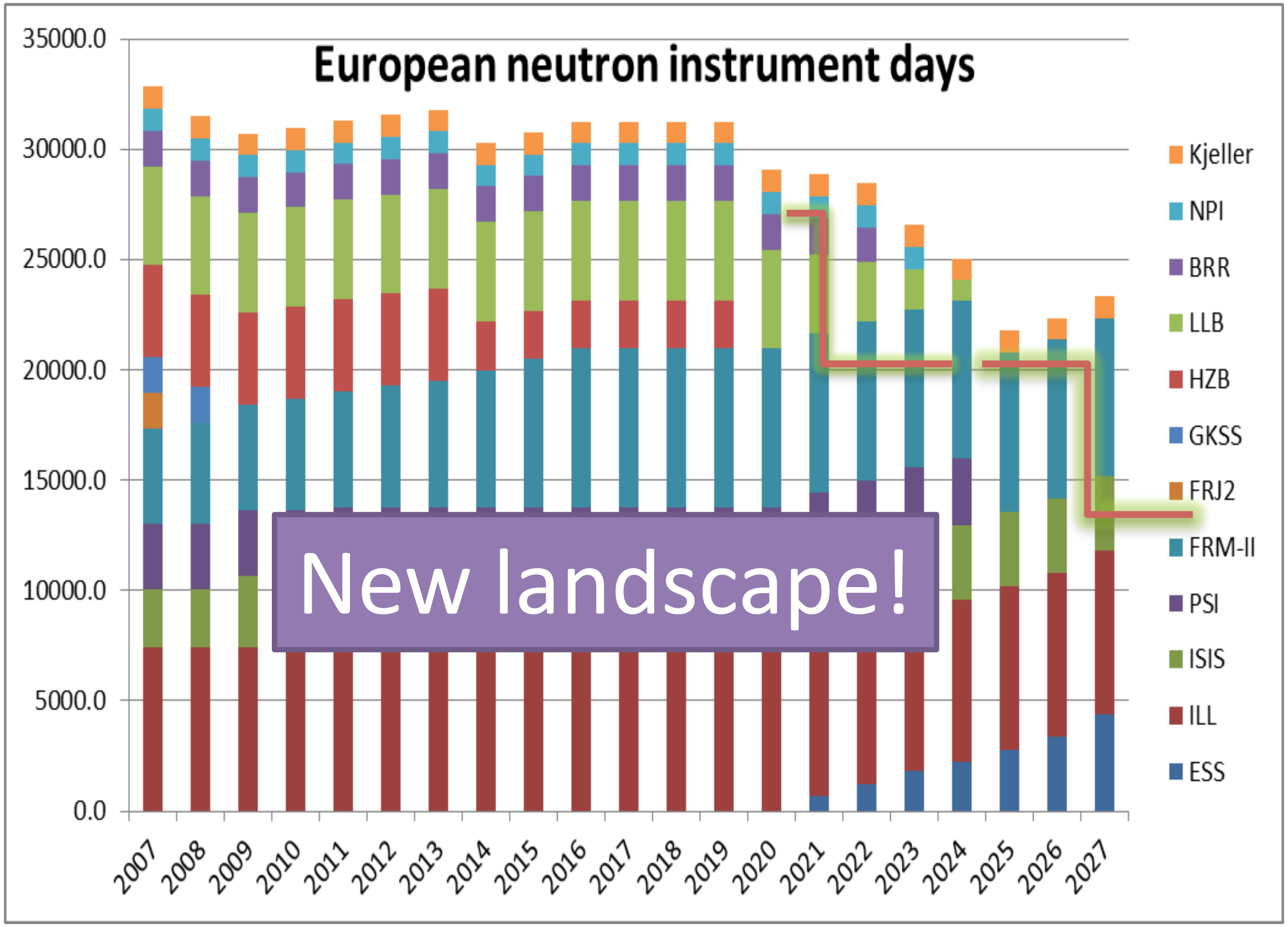
Astrophysics
(where do the heavy
elements come from?)

red giant stars (s-process)

super nova (r-process)

European neutron instrument days =
= (facility operajng days) x (number of operajonal instruments).

In practice days delivered to users will be 80--85% of this value

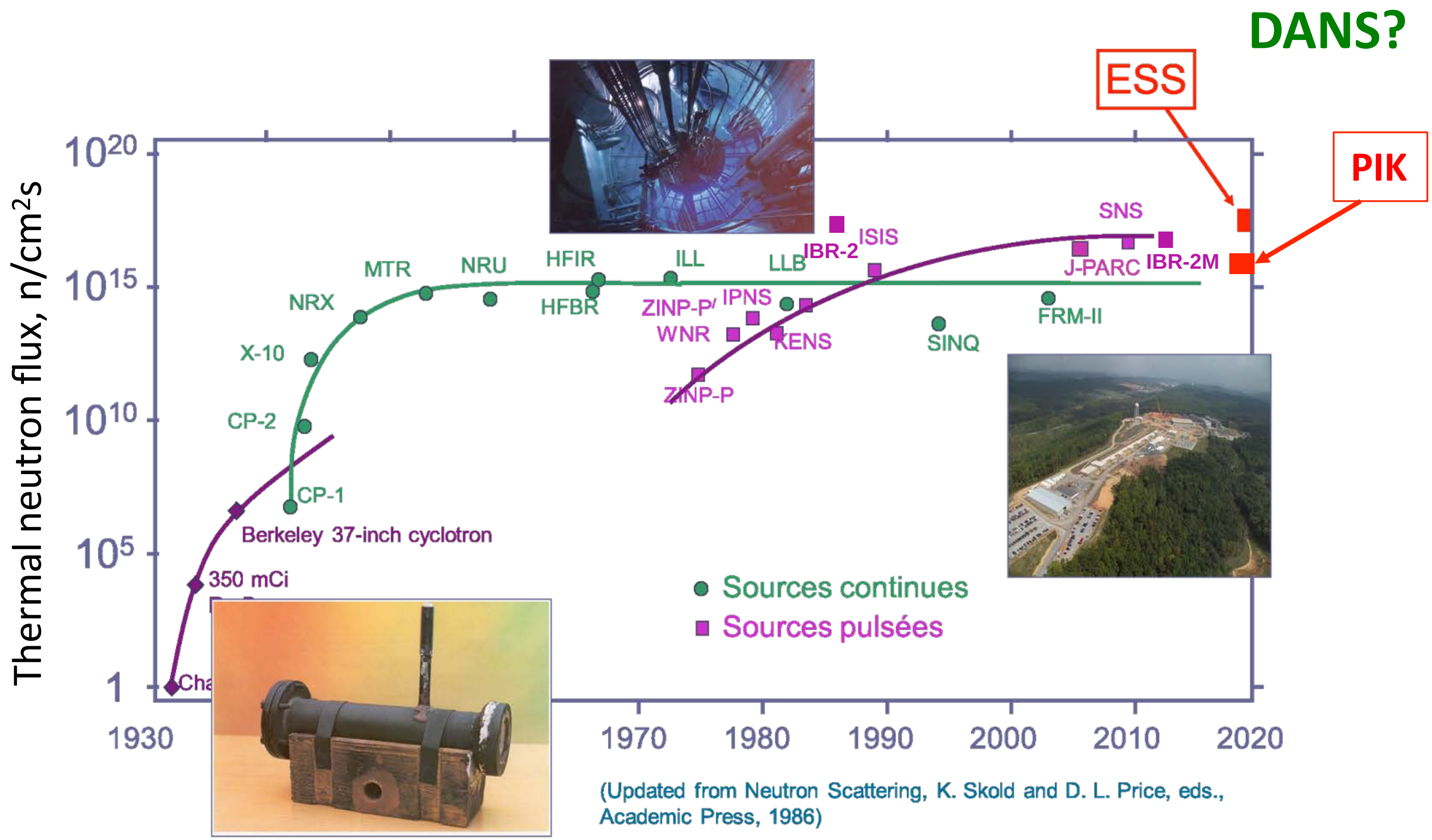


UK NS Roadmap by R.McGreevy

What will we have?

- new projects

Neutron Sources: fluxes



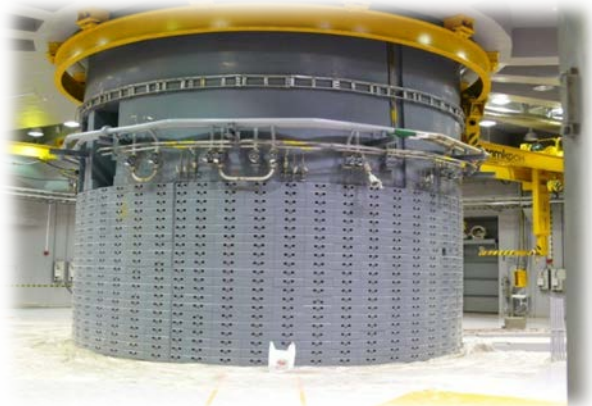
(Updated from Neutron Scattering, K. Skold and D. L. Price, eds., Academic Press, 1986)

But the real gain comes from the technical progresses on the neutron instruments!

Central part of the reactor complex PIK

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

Petersburg Nuclear Physics Institute of the NRC "Kurchatov Institute"

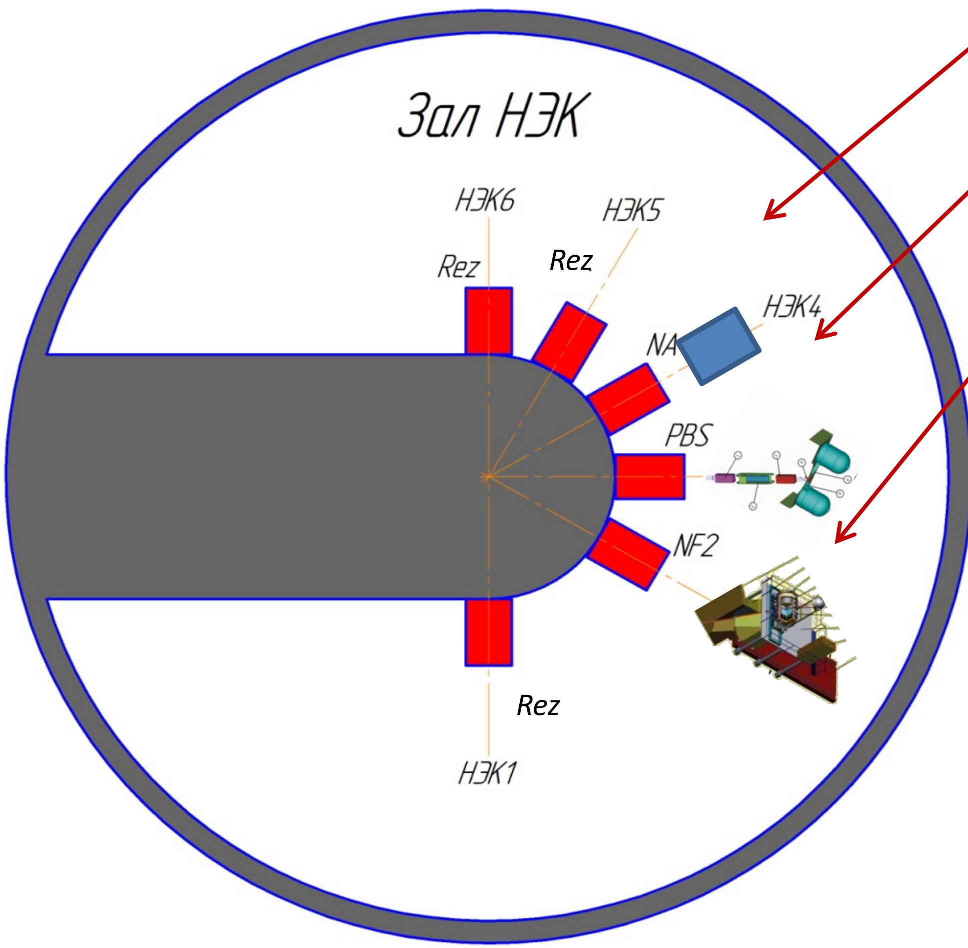
The project aiming to equip RC PIK with the modern experimental stations for the multidisciplinary research will be started and completed within the period between 2015 and 2020.

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
«KURCHATOV INSTITUTE»

PETERSBURG NUCLEAR PHYSICS INSTITUTE
Russia, 188300, Leningrad District, Gatchina, Orlova Roscha

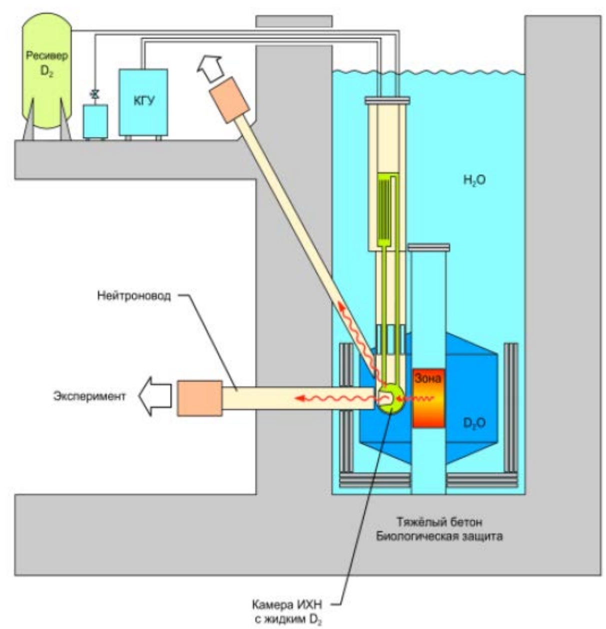
Hall of Inclined Channels (3)



NA - Neutron Activation Analysis.

PBS - Nuclear spectroscopy in the capture of thermal neutrons

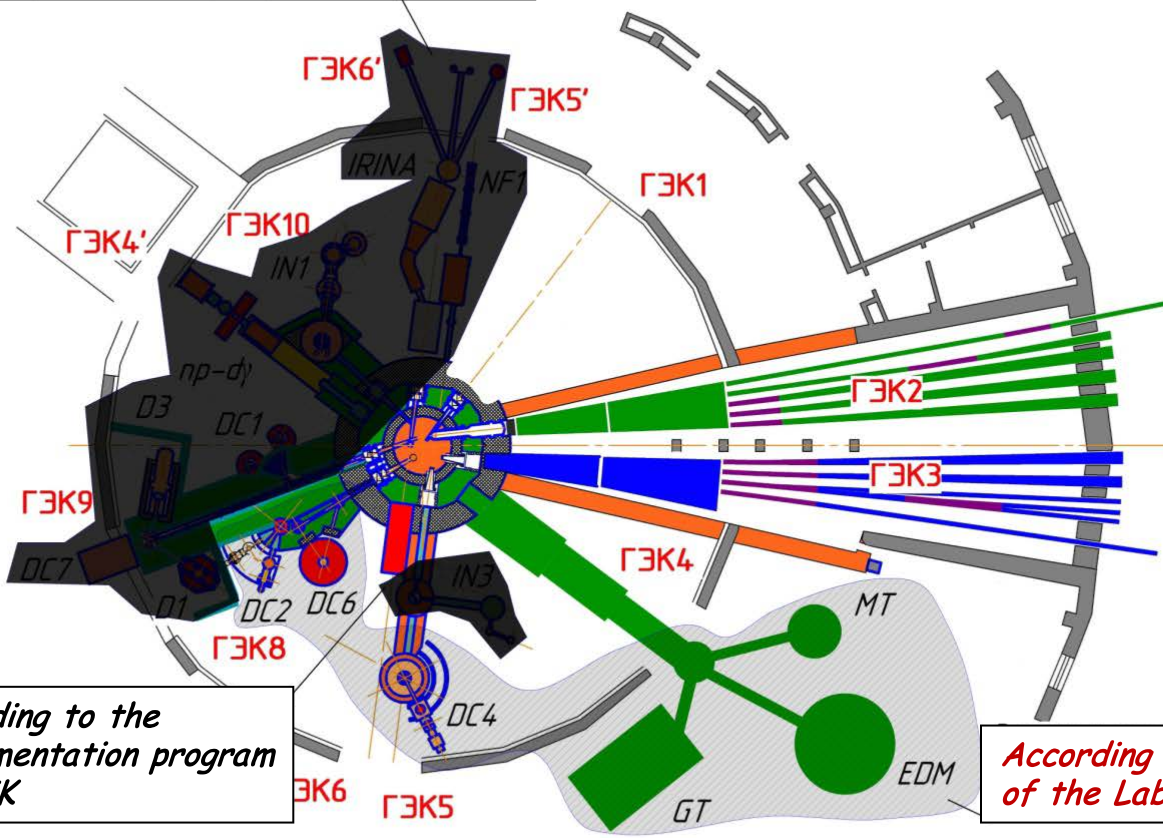
NF2 - Correlation investigations in fission



Reconstruction of the Laboratory Complex PIK

Hall of Horizontal Channels

According to the instrumentation program for PIK



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

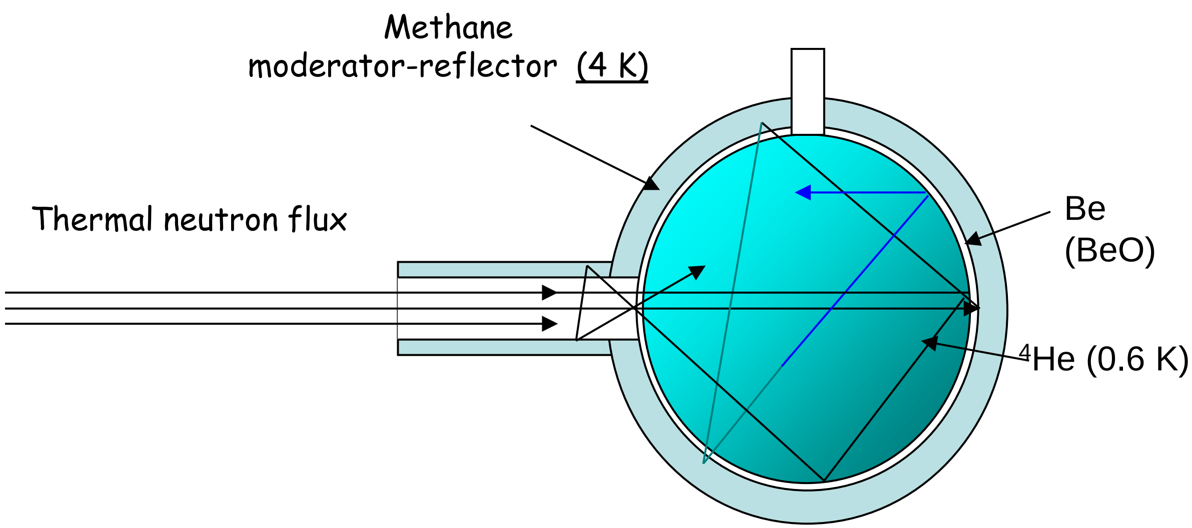
According to the instrumentation program for PIK

According to Project for Reconstruction of the Laboratory Complex PIK

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

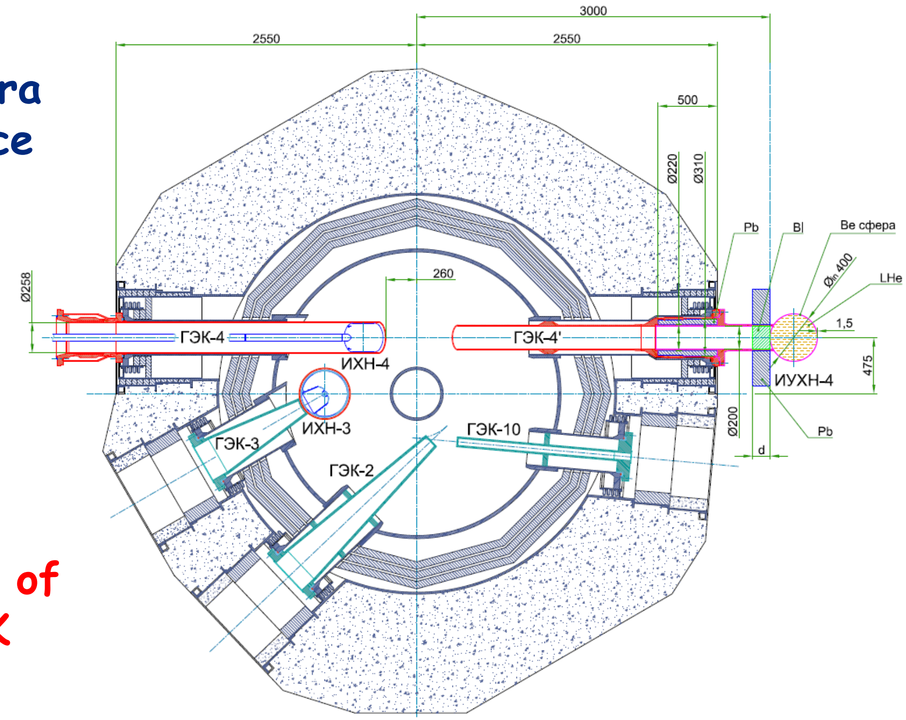
- DC4 - polarized neutron diffractometer with a two-dimensional detector POLDI
- DC6 - Texture diffractometer TEX
- DC2 - Stress diffractometer ARES

Helium Ultra Cold Neutron Source



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)

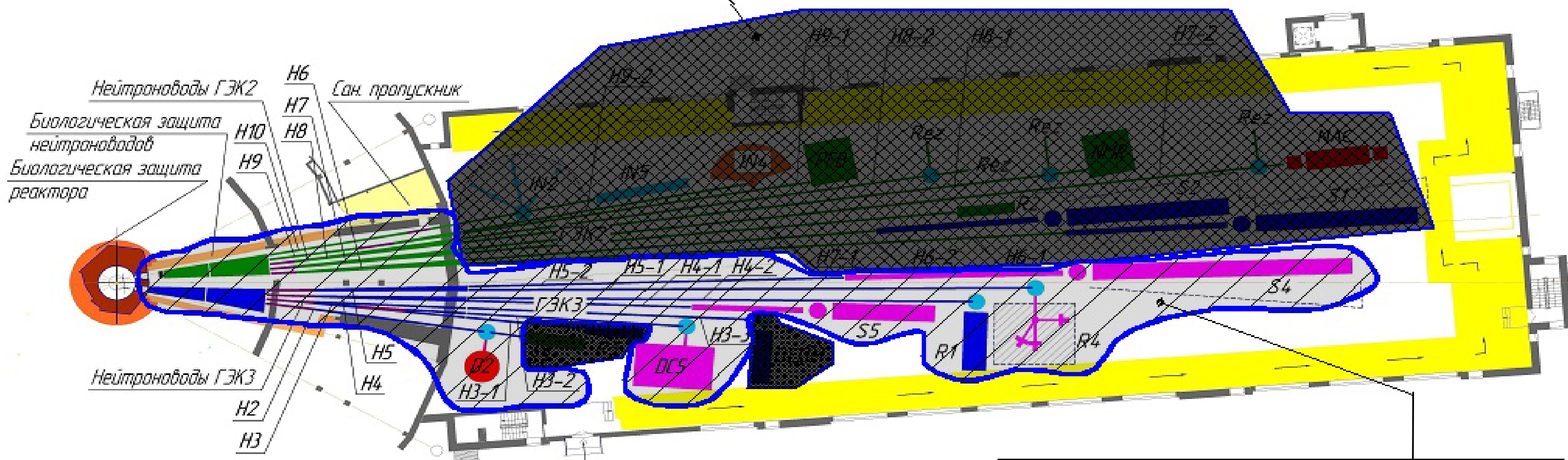


Placement option on extracted channel of thermal neutrons of the reactor PIK

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

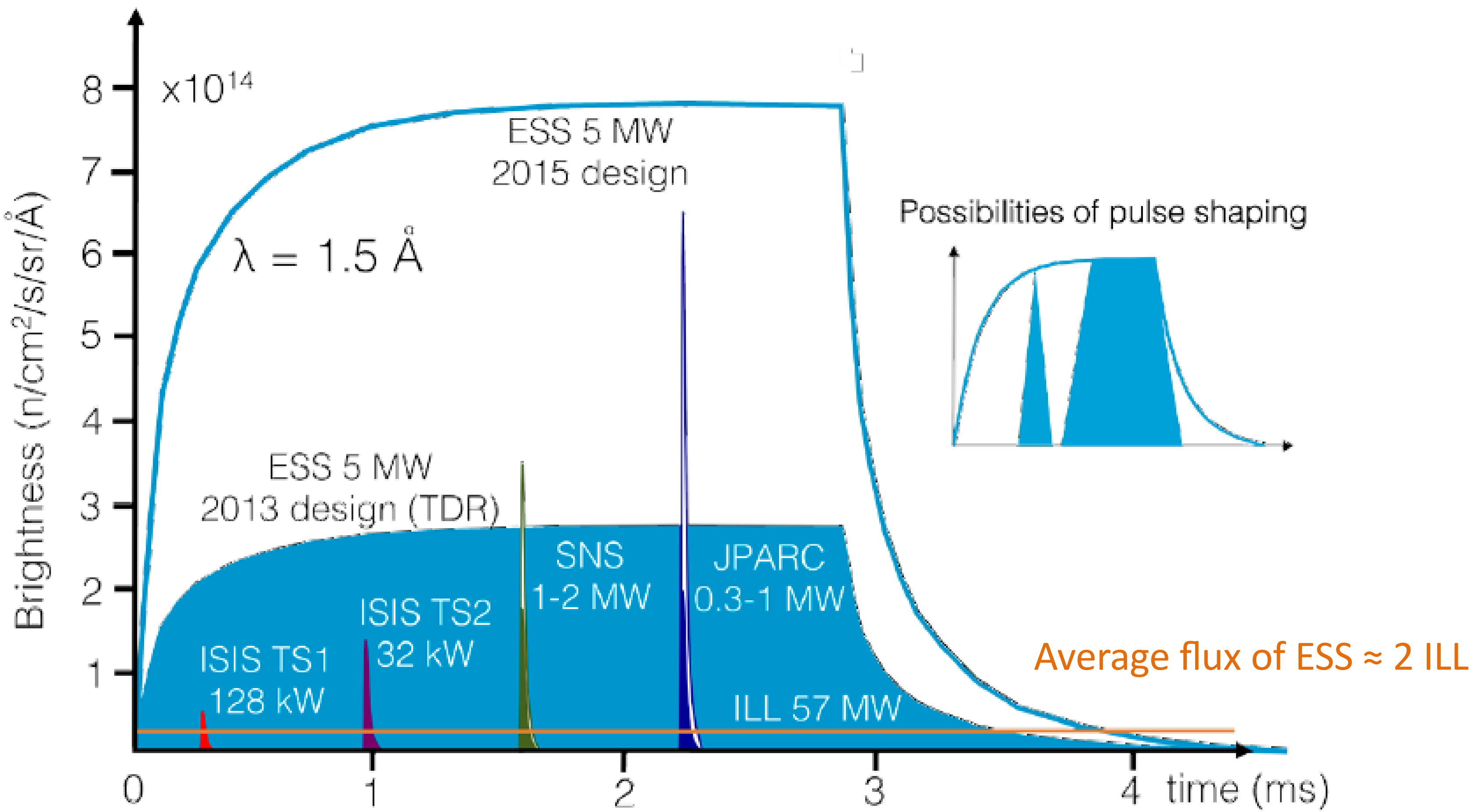
- D2 - powder diffractometer of cold neutrons
- R1 - polarized neutron reflectometer with a vertical plane of reflection REVERANS

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

EUROPEAN
SPALLATION
SOURCE

ESS vs. other spallation sources



Single-pulse source brightness as a function of time at a wavelength of 1.5 A at ESS, ILL, SNS, J-PARC and ISIS Target Stations 1 and 2.
In each case, the thermal moderator with the highest peak brightness is shown.

Source: ESS

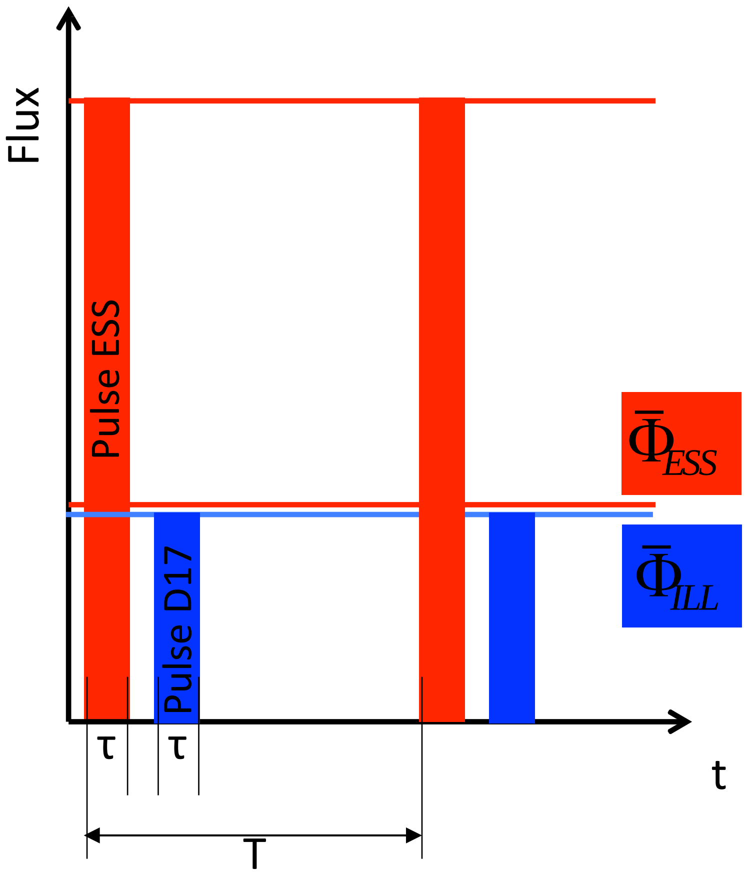
What ESS can give us?
A TOF instrument at ILL vs. a TOF instrument at ESS

If we will use the full ESS pulse, then:

$$\bar{\Phi}_{ILL} \approx \bar{\Phi}_{ESS}$$

$$\Phi_{D17} = \frac{\tau}{T} \Phi_{ESS\ Refl} \approx \frac{1}{25} \cdot \Phi_{ESS\ Refl}$$

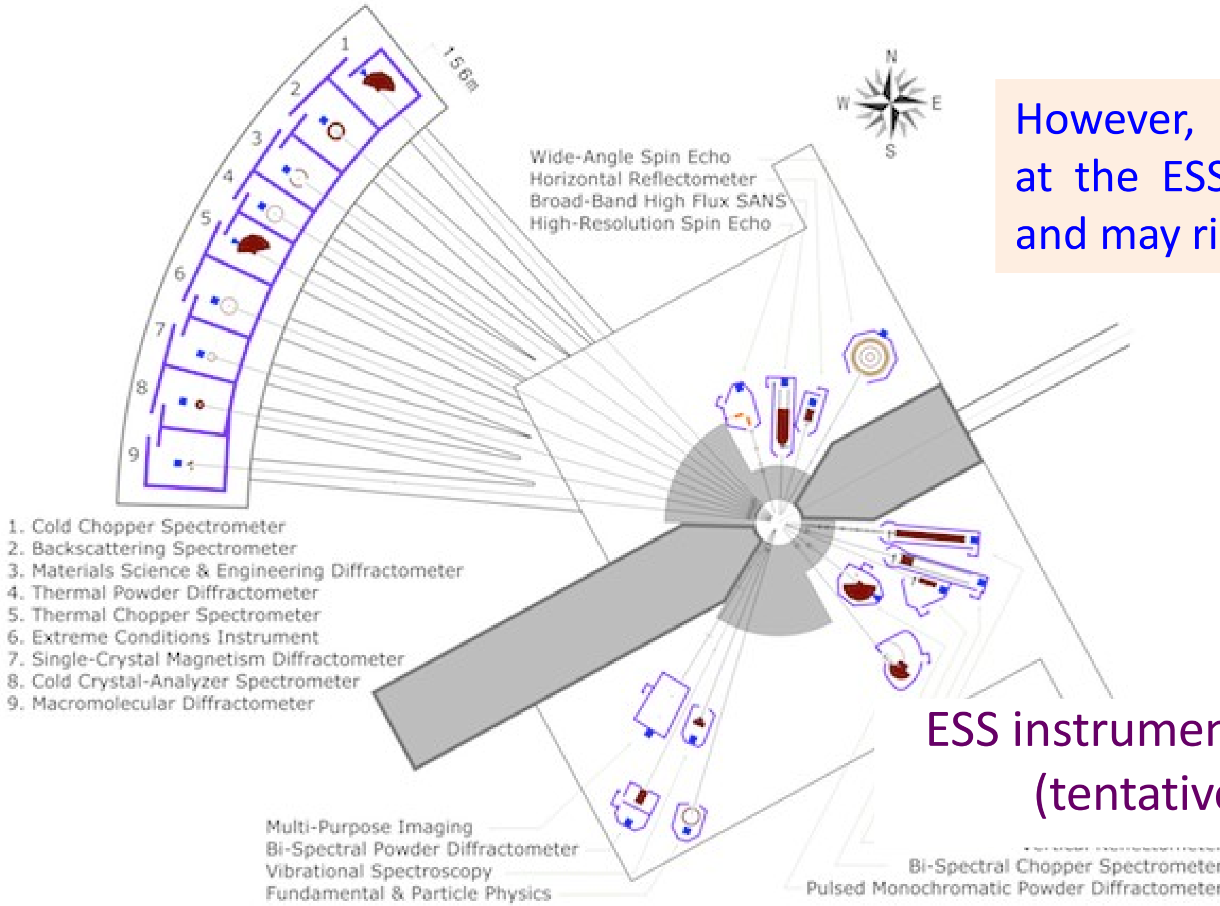
$$\tau_{ESS} = 2.8ms \qquad T_{ESS} = 72ms$$



Gain against ILL is about 25! Taking into account more modern neutron optics – 30-40!

Flat moderator – another factor 2.5-3. thus, for instruments using focusing optics the gain vs. ILL will be about 100!

A. Ioffe



ESS instrument plan
(tentative)

However, the number of instruments at the ESS is limited by only 16 (2022) and may rise to 22 instruments (2026).

IBR-2 14 instruments

PIK 12 instruments (2019)
32 instruments (2025)

ILL – about 40 instruments, MLZ– about 35 instruments

- when they will be phased out – much less instruments than today
- Inevitable loss of European user base
- Compact neutron sources (10 to be build in Japan – similar situation)
- **PIK!**

DANS – Dubna Advanced Neutron Source

On behalf of V.D.Ananiev, S.N.Dolya, Yu.N.Pepelyshev, E.P.Shabalin, A.V.Vinogradov

Proton linear accelerator:

$E_p \leq$ 0.6 GeV, $\bar{i} \leq$ 0,2mA, 100mks, 10Hz

Multiplaying target:

PU-239 or U-233, multiplication 20÷30

Peak thermal neutron flux

$\Phi_n \approx 3\ \Phi_n^{ess}$

THANKS FOR YOUR ATTENTION!