Present status and future prospects of nEDM experiment of PNPI-ILL-PTI collaboration

A.P. Serebrov,

PNPI Scientific Research Center KI, Gatchina, Russia

International Nuclear Physics Conference
Australia, 11 - 16 September 2016

Baryon Asymmetry in our Universe

Electroweak SM expectation:

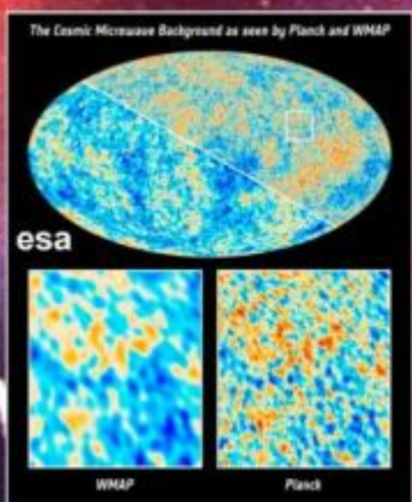
$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-18}$$

vs.

Observed*:

$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 6 \times 10^{-10}$$

Connection between Cosmology and SM of Particle Physics !



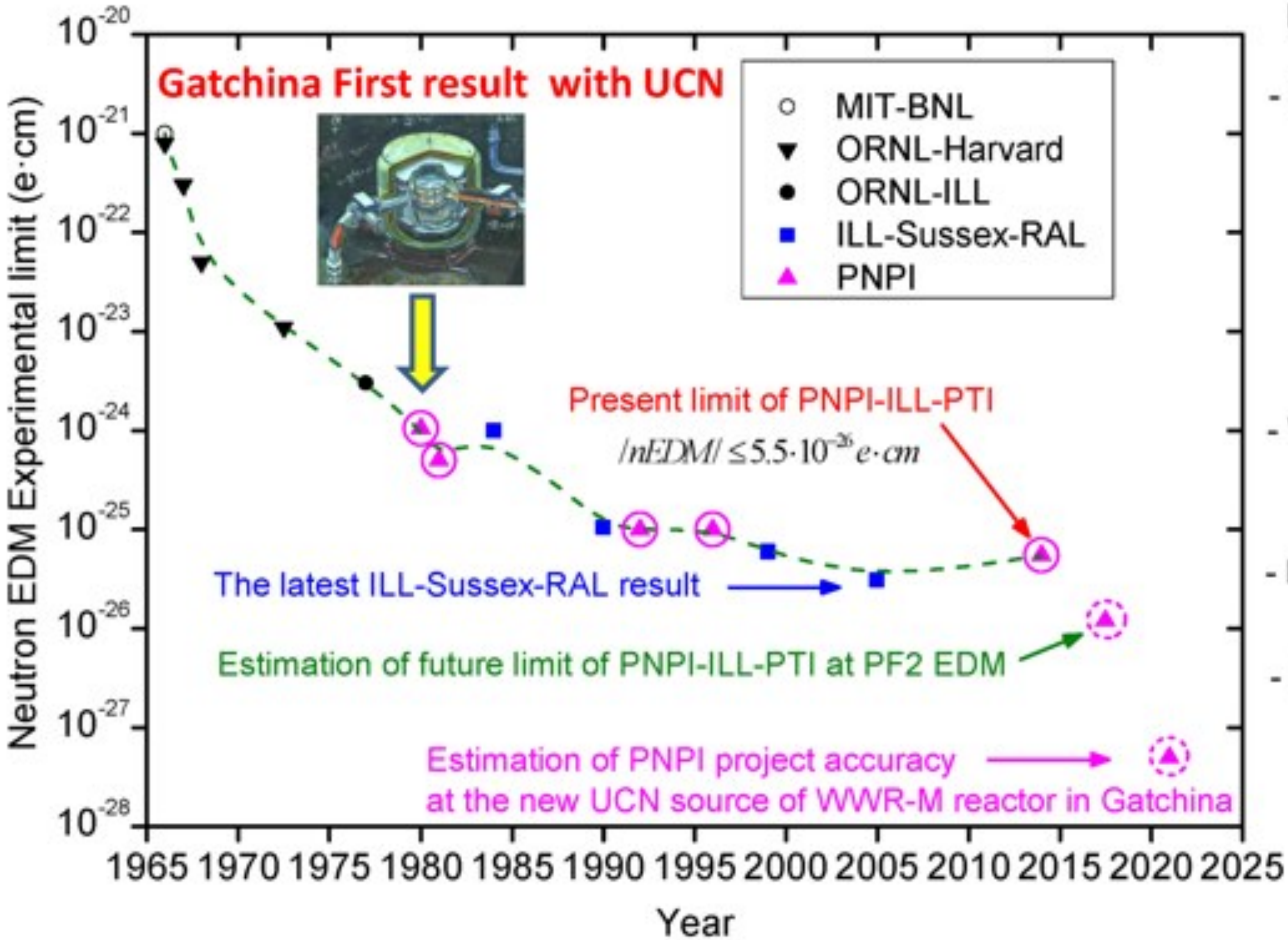
Sakharov criteria for Baryogenesis in the early universe:

1. *Baryon number violation*
2. *C and CP violation*
3. *Thermal non-equilibrium*

JETP Lett. 5, 24 (1967)

* e.g. WMAP, COBE, Planck

History of nEDM measurements in Gatchina and Grenoble. Result and prospects of PNPI-ILL-PTI collaboration

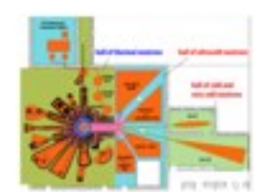


Theoretical Prediction:

- Electromagnetic
- Weinberg Multi-Higgs
- Minimal SUSY

Cosmology

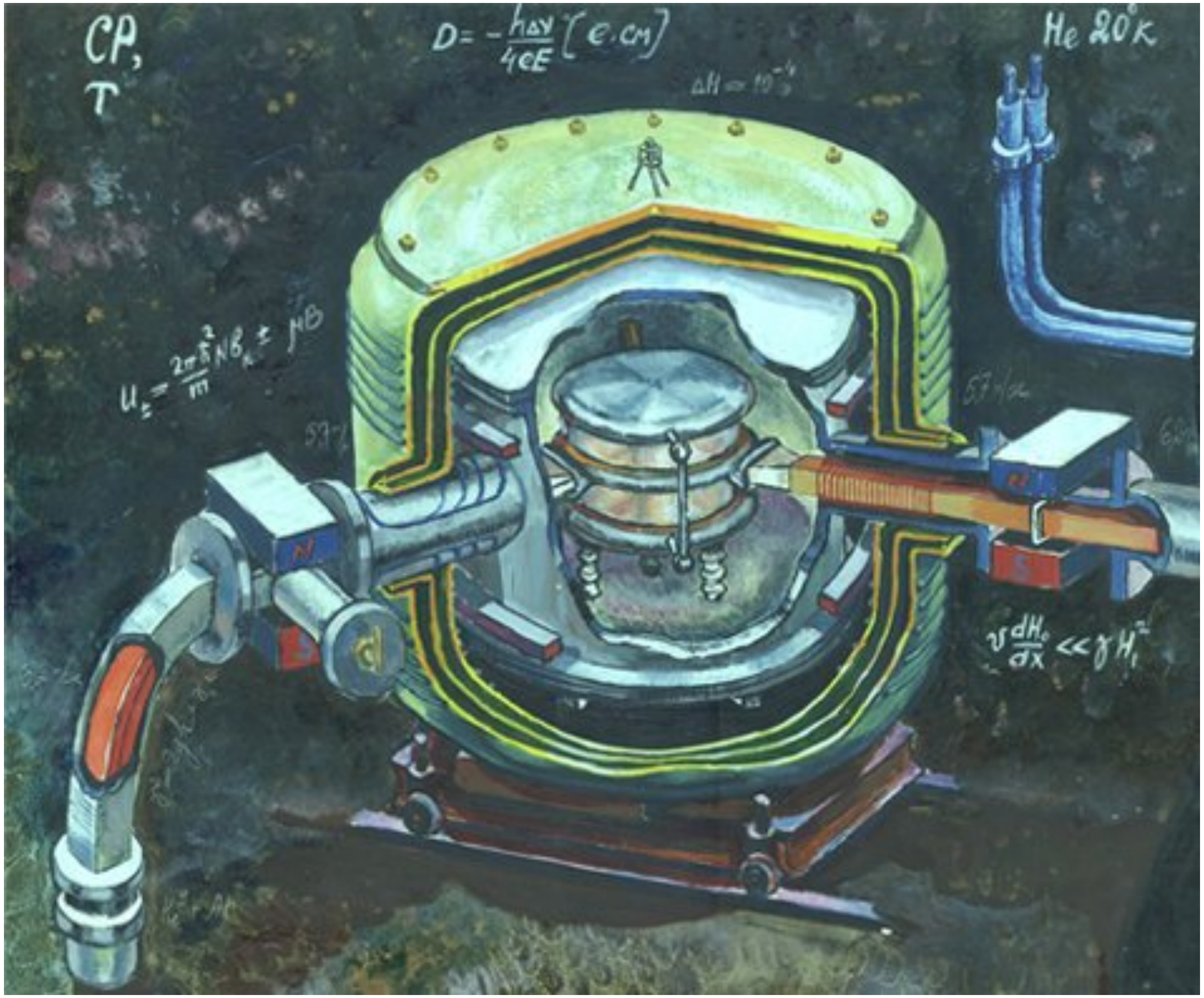
- Left-Right Symm.



UCN source at WWR-M reactor

Serebrov. Mainz

Gatchina EDM spectrometer 1975

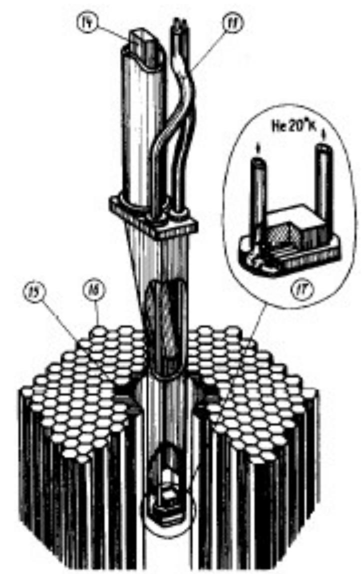


The first result for nEDM with UCN method

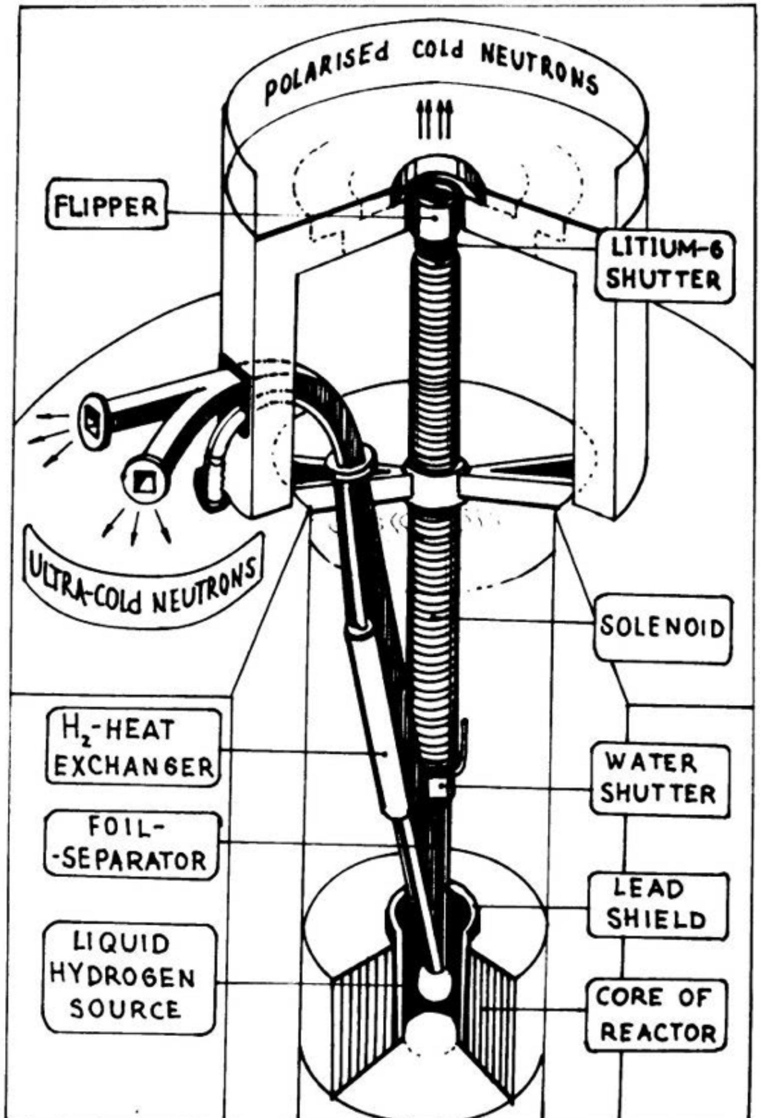
$|d_n| < 1.6\cdot10^{-24}$ *e*·см

(90% C.L.)

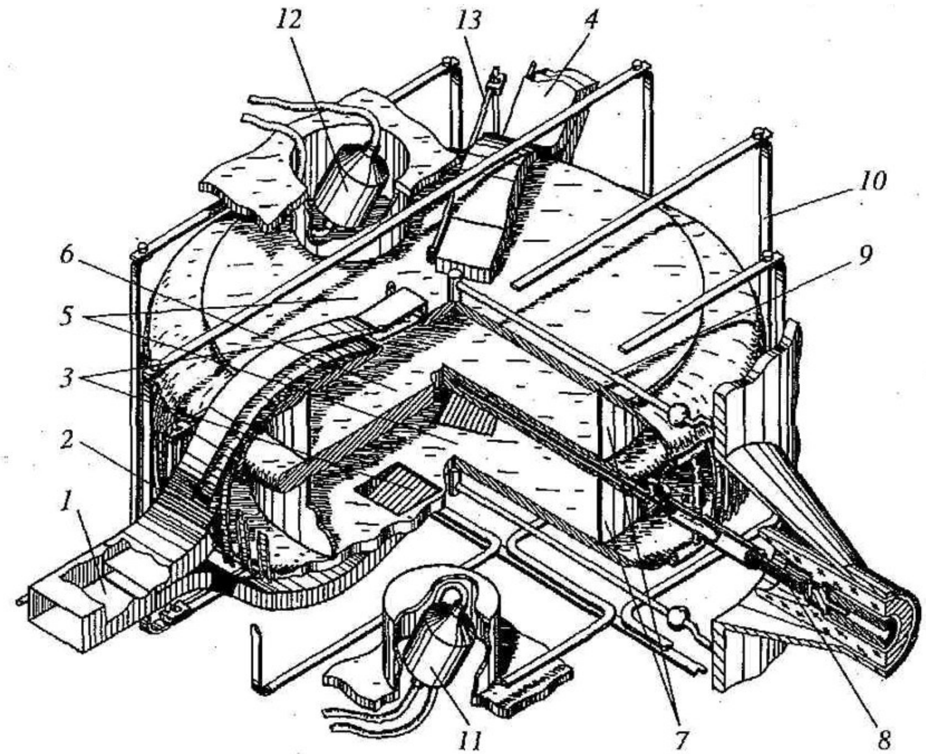
Altarev I.S. et al.,
Nuclear Physics A341 (1980) 269-283



Gatchina source of UCN and polarized cold neutrons   1985 -1996

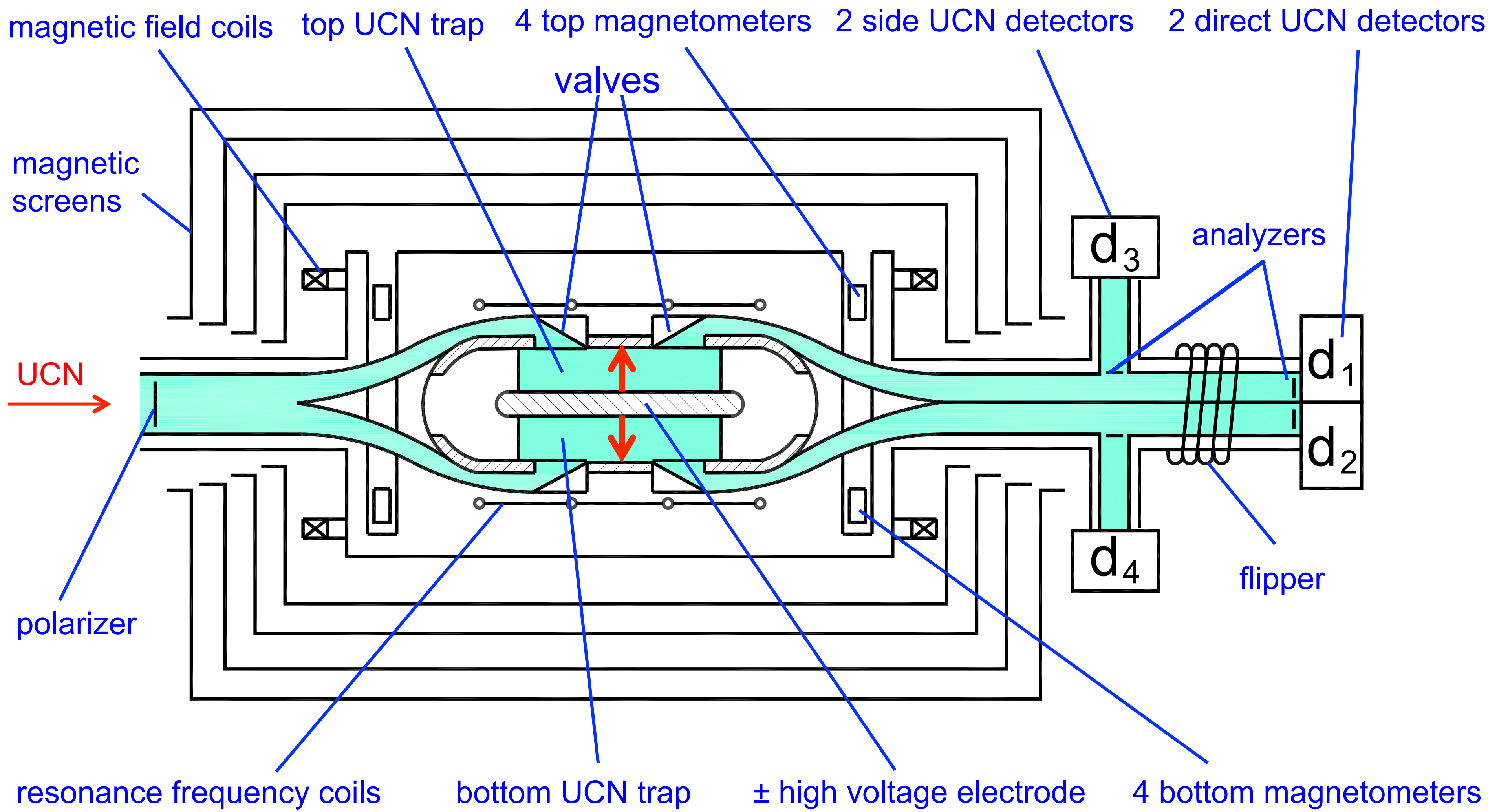


$|d_n| < 9.7 \cdot 10^{-26}$ *e*·cм
(90% C.L.)



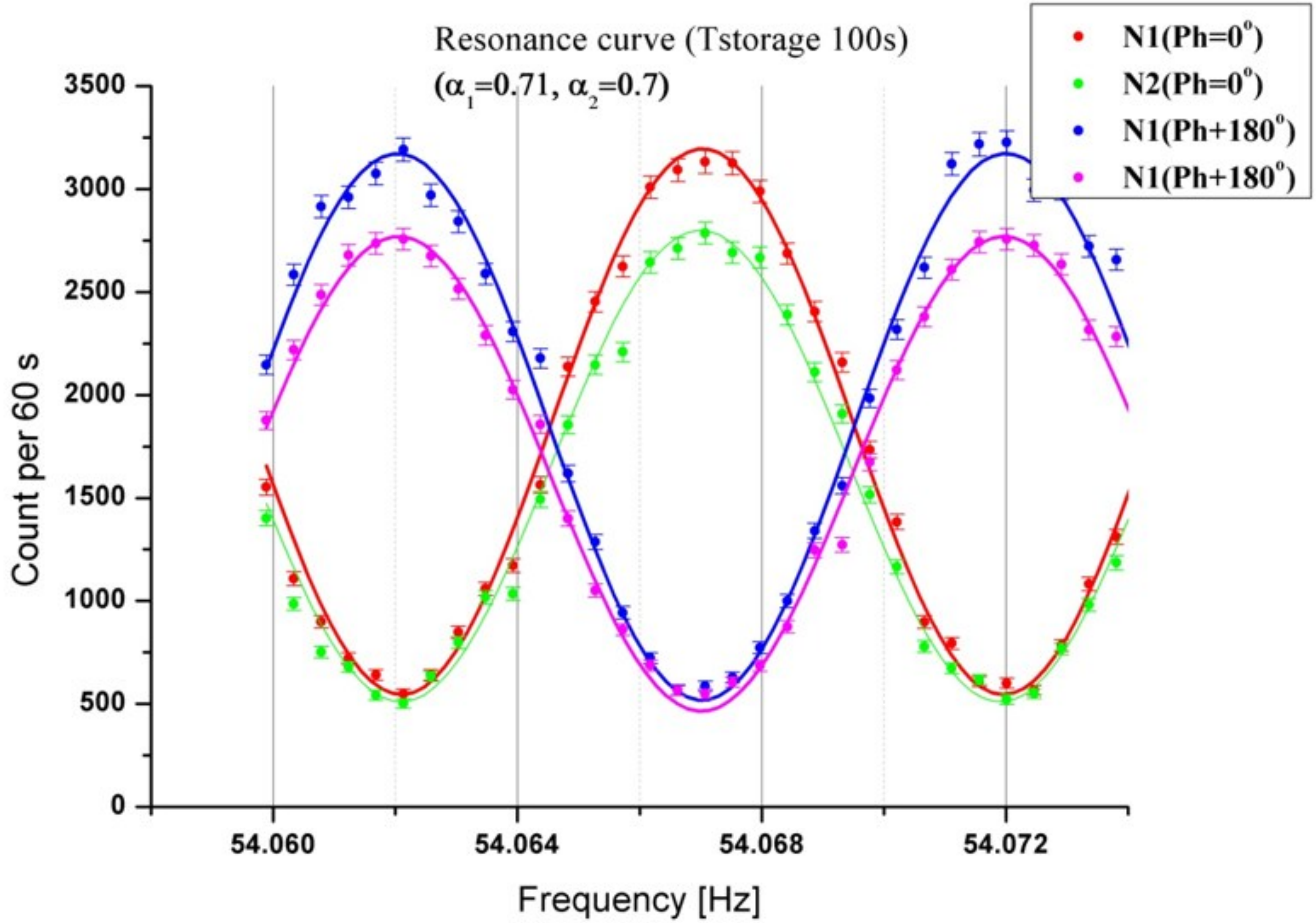
September 2008 - Assembly and testing of detectors, magnetometers and electronics.
October 2008 - Start of the first measurements with the neutrons

Scheme of EDM spectrometer



Resonance curves for holding time 100s

$$\alpha = \frac{N_{max} - N_{min}}{N_{max} + N_{min}} \qquad \alpha_1 = 0.71; \quad \alpha_2 = 0.70$$



Principal scheme of measurements with false effect control

$$\left.\begin{array}{l} d_1 \text{ - top trap} \\ d_2 \text{ - bottom trap} \end{array}\right\} \text{direct detectors}$$

$$\left.\begin{array}{l} d_3 \text{ - top trap} \\ d_4 \text{ - bottom trap} \end{array}\right\} \text{side detectors}$$

$$EDM = \frac{1}{4}\left[\left(d_1 + d_2\right) + \left(d_3 + d_4\right)\right]$$

EDM **is EDM effect**

$$\nu = \frac{1}{4}\left[\left(d_1 - d_2\right) + \left(d_3 - d_4\right)\right]$$

$\boldsymbol{\nu}$ is effect of influence of electric polarity changing on the resonance conditions (magnetic field or frequency)

$$N^{(*)} = \frac{1}{4}\left[\left(d_1 - d_2\right) - \left(d_3 - d_4\right)\right]$$

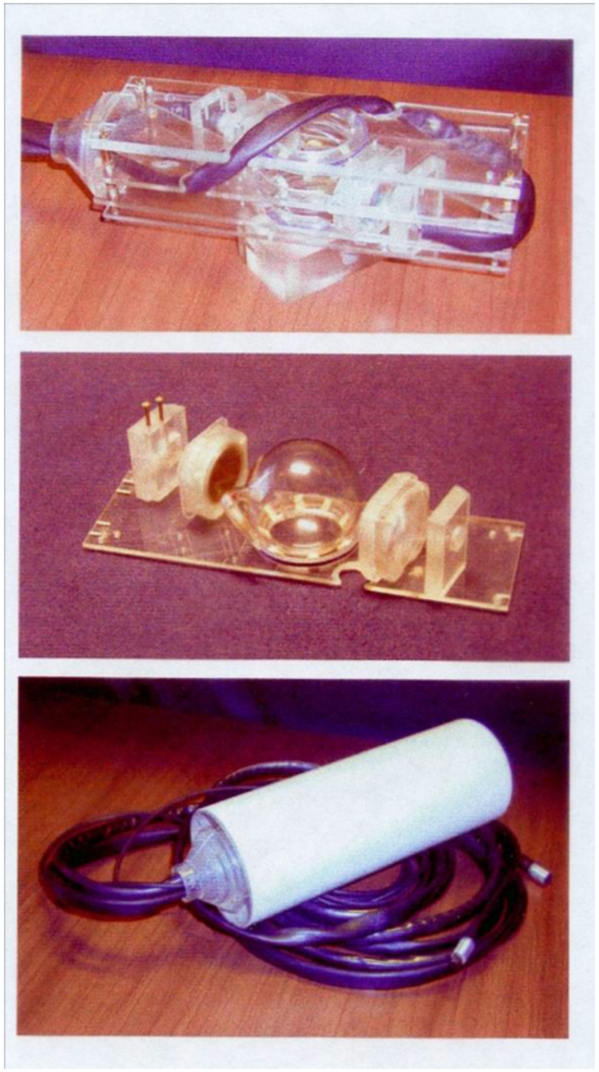
N is effect of influence of electric polarity changing on the detector counting rate

$$z = \frac{1}{4}\left[\left(d_1 + d_2\right) - \left(d_3 + d_4\right)\right]$$

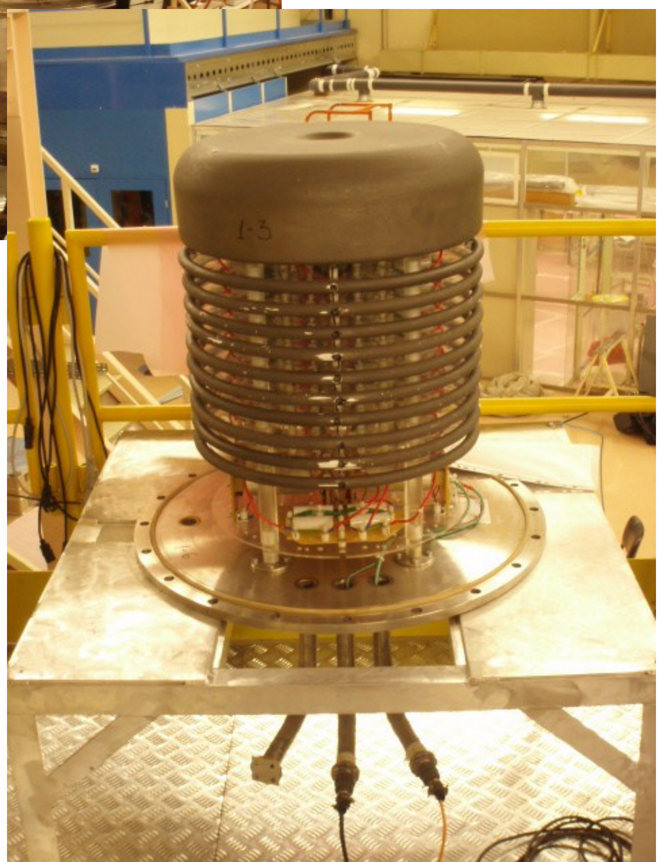
Z is compensation of all effects, including EDM effects

(*) Difference of measurements for 90° and 180°

Preparation of Cs-magnetometers at PTI

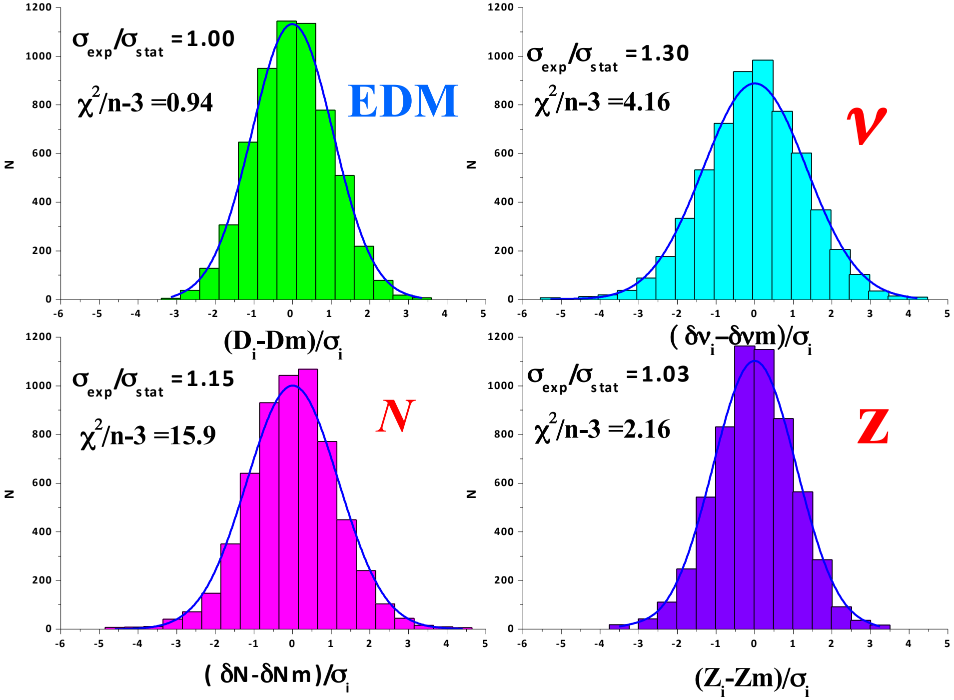


The best result with HV (+_)175kV/ 8.7cm = 20kV/cm



Results of measurements in units 10^{-26} e·cm

	Old	New	All
EDM	0.7±4.0	0.363±4.68	0.56±3.04
ν	-22.8±9.2	-10.04±5.98	-13.8±5.01
N	-14.5±4.4	18.62±5.15	-0.53±3.35
Z	-0.8±4.0	3.68±4.72	1.05±3.05



$/nEDM/ \leq 5.5 \cdot 10^{-26}$ e·cm

90% CL

OUR current result

$$/nEDM/ \leq 5.5 \cdot 10^{-26} e \cdot cm$$

90% CL

Present limit of RAL/Sussex

$$/nEDM/ \leq 3 \cdot 10^{-26} e \cdot cm$$

90% CL

JETP Letters, 2014, Vol. 99, No. 1, pp. 4–8. © Pleiades Publishing, Inc., 2014.

New Measurements of the Neutron Electric Dipole Moment¶

A. P. Serebrov[a], E. A. Kolomenskiy[a], A. N. Pirozhkov[a], I. A. Krasnoschekova[a], A. V. Vassiljev[a], A. O. Polushkin[a], M. S. Lasakov[a], A. K. Fomin[a], I. V. Shoka[a], V. A. Solovey[a], O. M. Zherebtsov[a], P. Geltenbort[b], S. N. Ivanov[b], O. Zimmer[b], E. B. Alexandrov[c], S. P. Dmitriev[c], and N. A. Dovator[c]

[a] *Konstantinov Petersburg Nuclear Physics Institute, National Research Centre Kurchatov Institute, Gatchina, 188300 Russia*

e-mail: serebrov@pnpi.spb.ru

[b] *Institut Max von Laue–Paul Langevin BP 156, Grenoble Cedex 9, 38042 France*

[c] *Ioffe Physical Technical Institute, Russian Academy of Sciences, St. Petersburg, 194021 Russia*

Received December 10, 2013

PHYSICAL REVIEW C **92**, 055501 (2015)

The measurement of nEDM at ILL

New search for the neutron electric dipole moment with ultracold neutrons at ILL

A. P. Serebrov,* E. A. Kolomenskiy, A. N. Pirozhkov, I. A. Krasnoschekova, A. V. Vassiljev, A. O. Polyushkin, M. S. Lasakov, A. N. Murashkin, V. A. Solovey, A. K. Fomin, I. V. Shoka, and O. M. Zherebtsov

B. P. Konstantinov Petersburg Nuclear Physics Institute of National Research Centre "Kurchatov Institute," 188300 Gatchina, Leningrad region, Russia

P. Geltenbort, S. N. Ivanov, and O. Zimmer

Institut Max von Laue – Paul Langevin, BP 156, 38042 Grenoble Cedex 9, France

E. B. Alexandrov, S. P. Dmitriev, and N. A. Dovator

Ioffe Physical Technical Institute RAS, 194021 St. Petersburg, Russia

(Received 16 February 2015; revised manuscript received 29 July 2015; published 5 November 2015)

Possible improvement of nEDM accuracy measurement at PF2

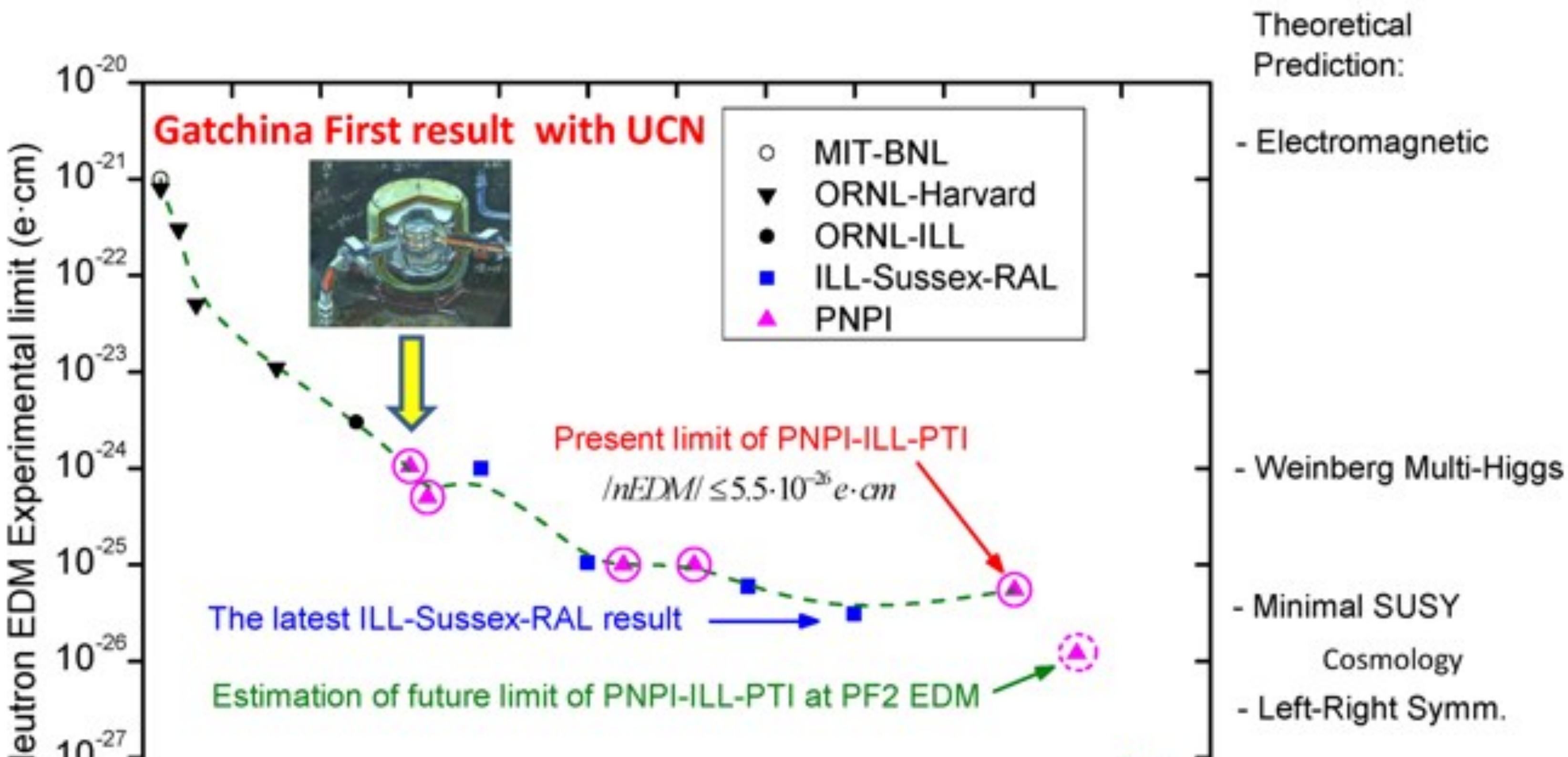
EDM spectrometer at the PF2 EDM position

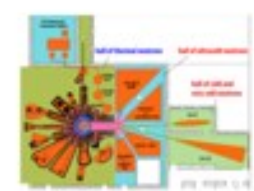
turbine

EDM spectrometer

installation “Big gravitrap”

History of nEDM measurements in Gatchina and Grenoble. Result and prospects of PNPI-ILL-PTI collaboration



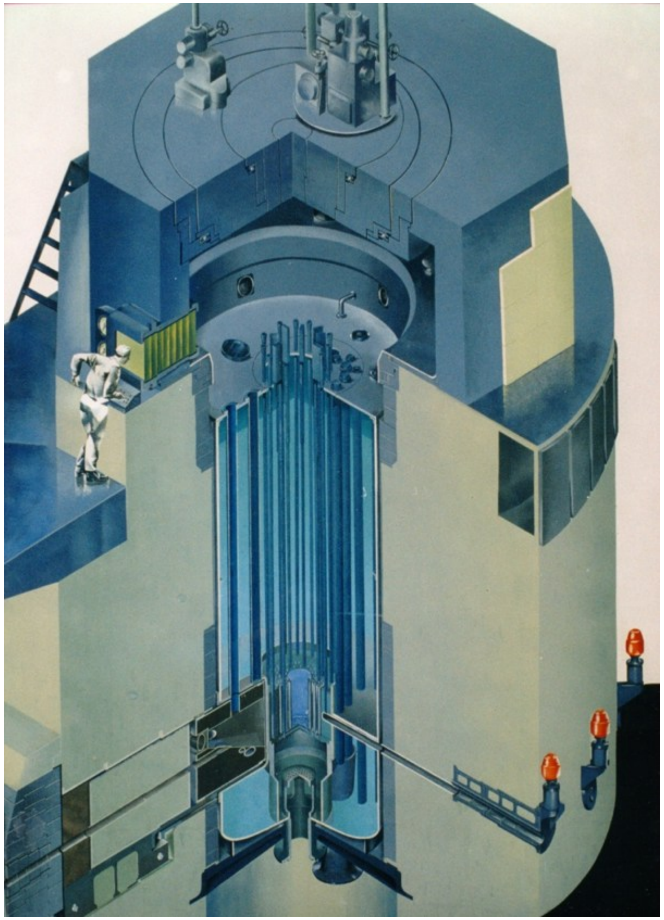


UCN source at WWR-M reactor

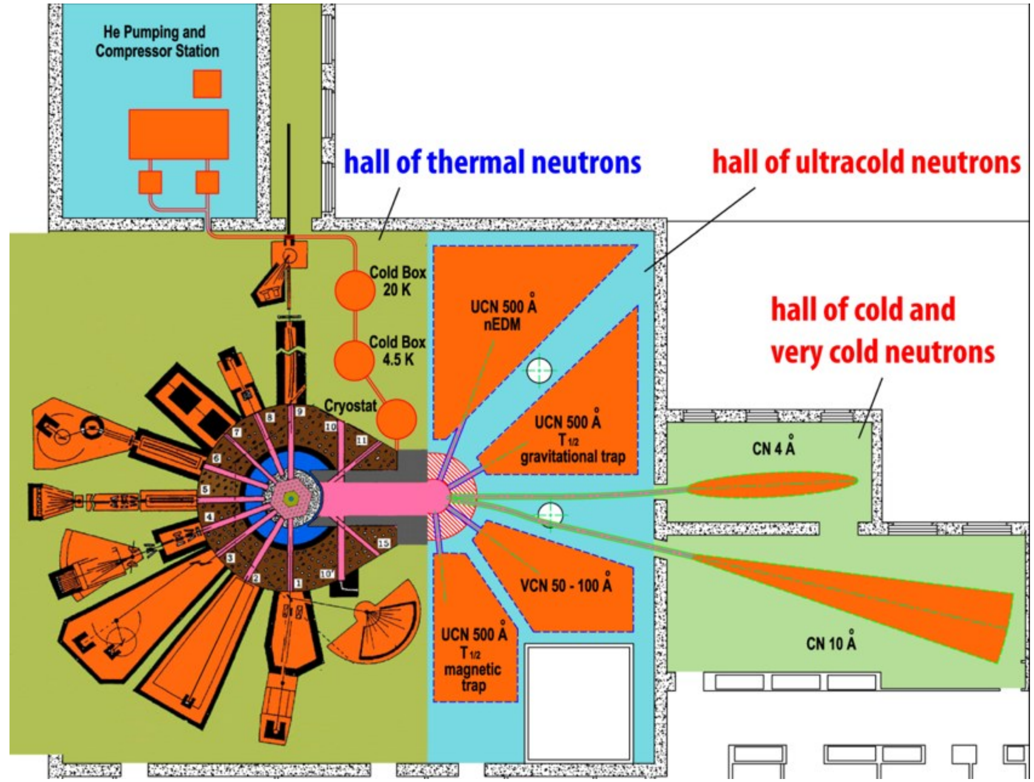
Serebrov. Mainz

Future prospects in Gatchina

Prospects for UCN source at WWR-M reactor

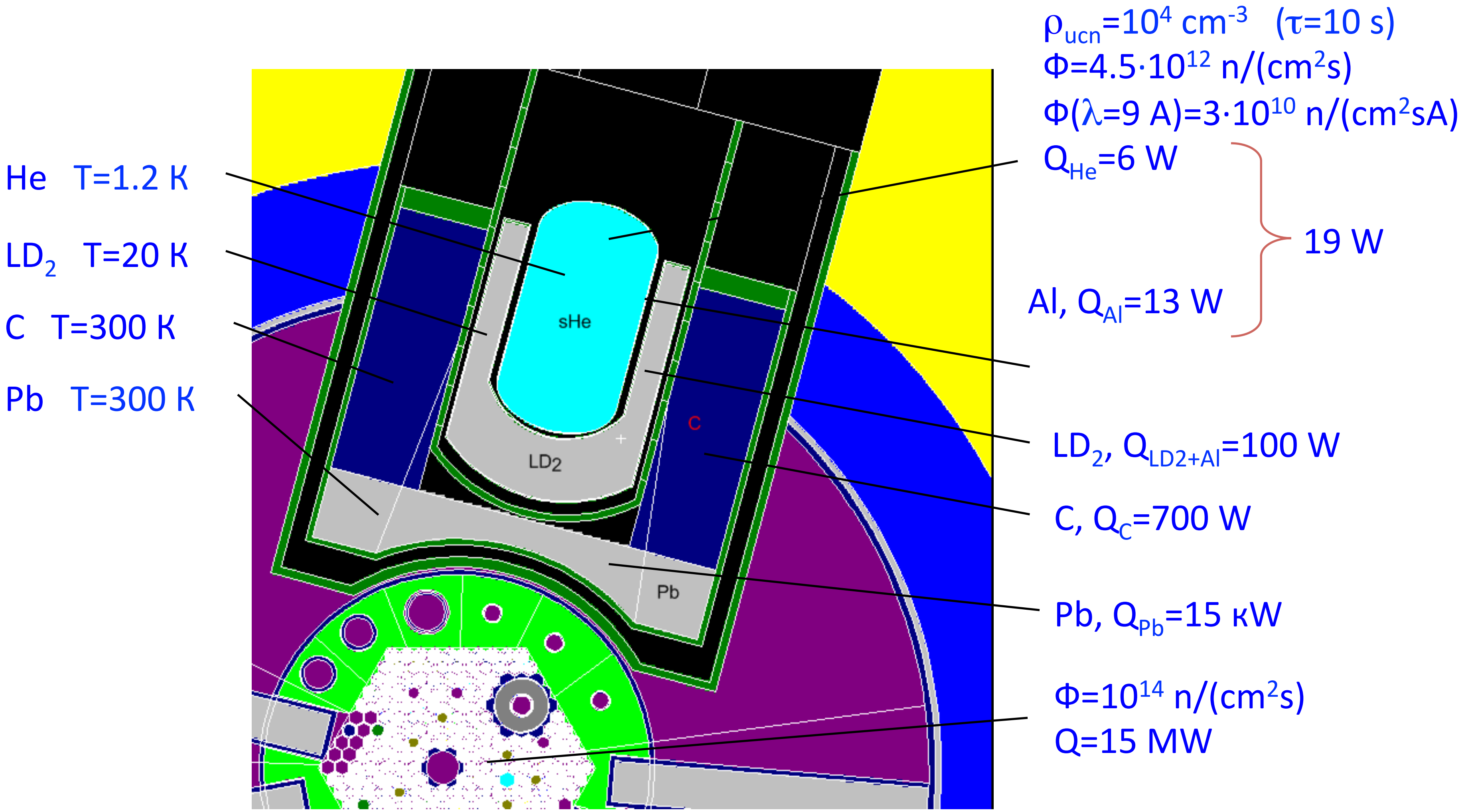


The resource of basic elements of the reactor provides its further operation within 25 years.



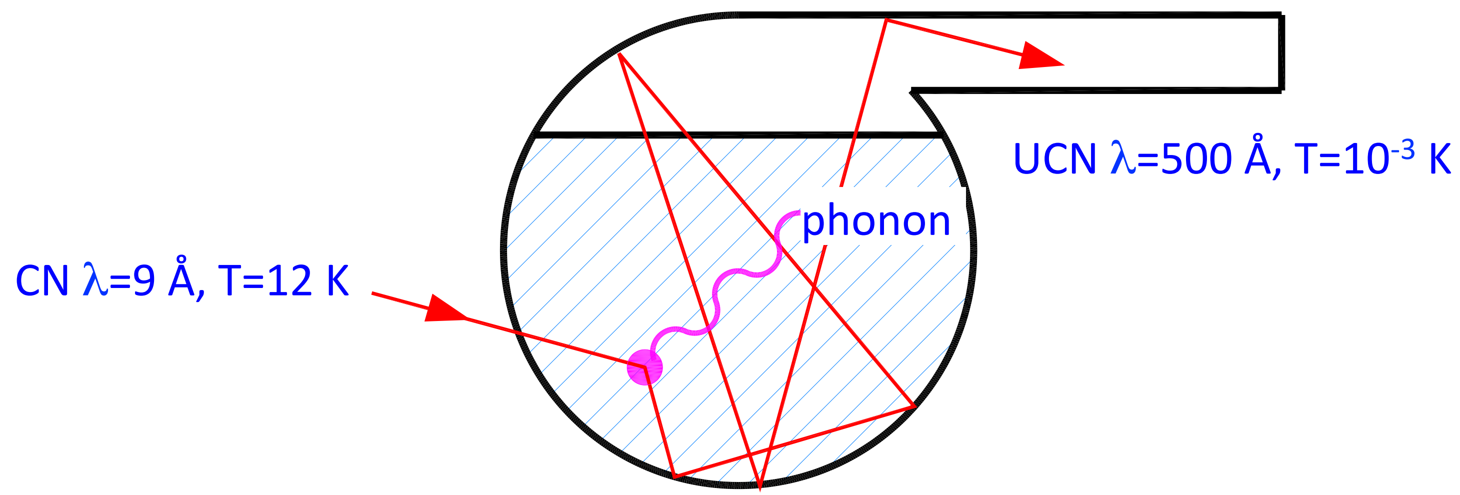
The scheme of experimental installations on the BBP-M reactor after installation in a thermal column of the reactor of UCN source with superfluid helium at a temperature of 1.2K.

MCNP neutron flux calculation results and heat generation in thermal column of WWR-M reactor at 15 MW



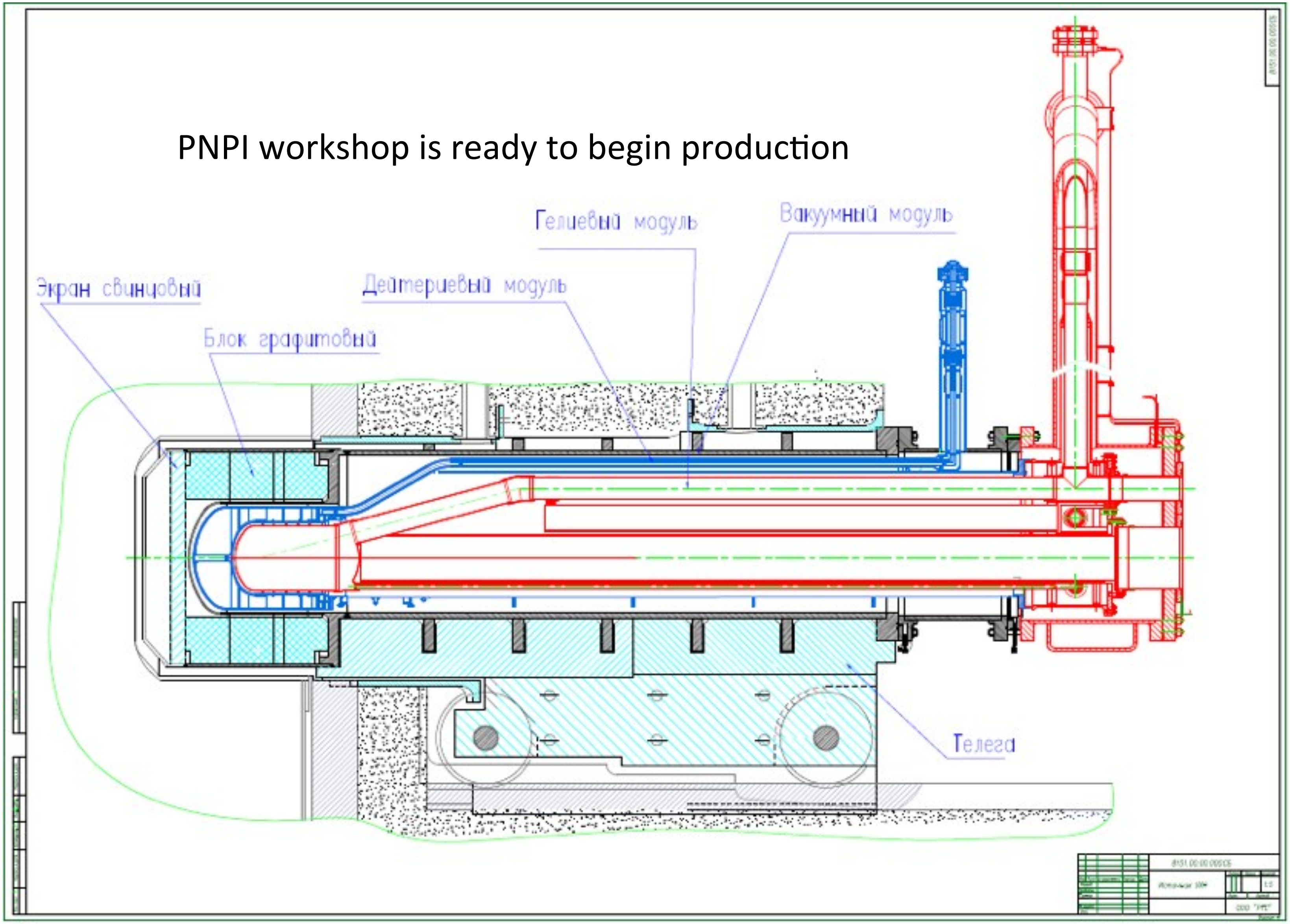
Principle of a source

UCNs are generated in helium from cold neutrons of 9Å wavelength (12 K energy). It is correspond with phonon energy: cold neutron produces phonon, practically stops and becomes an ultracold one. UCN can "lives" in superfluid helium for tens or hundreds of seconds until a phonon be captured.
Cold neutrons (9Å) penetrate through the wall of a trap, but ultracold neutrons (500Å) are reflected, that is why UCN can be accumulated up to the density defined by the time of storage in the trap filled with superfluid helium.



UCN source inside the thermal column of the WWR-M reactor

PNPI workshop is ready to begin production

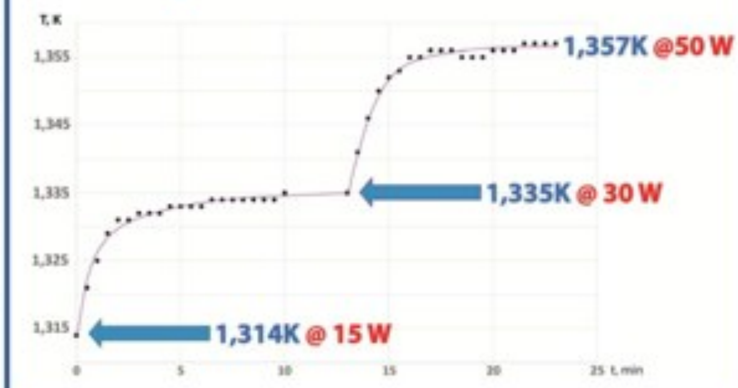


The full-scale model of UCN source with superfluid helium is tested up to 50 W at 1.3 K

It means that project can be realized. *(Possible UCN density in EDM trap is about* $10^4 cm^{-3}$ *)*

November 2015

Temperature - from heat load



Refrigerator 20 K **Cryostat 1 K** **Liquefier 4 K**

Vacuum pumps system with a total capacity of 120000 cub.m/hour

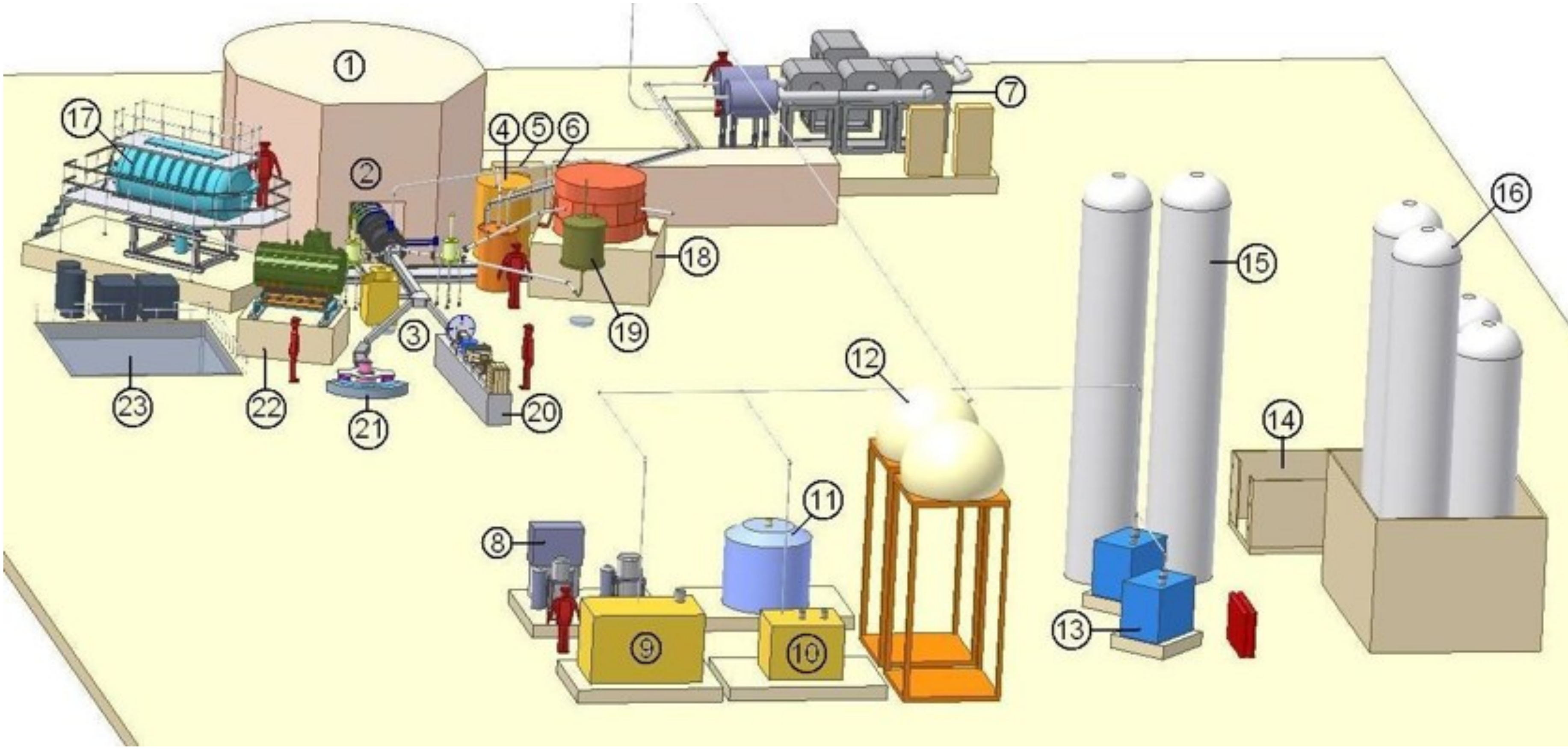
The pumps are equipped with 2 heaters that warm helium up to the room temperature

Vacuum pumps are controlled by frequency converter, allowing to adjust the pump performance (according to helium temperature)

Cryogenic building at WWR-M reactor
Full-scale UCNS model complex with superfluid helium

Full-scale UCNS model complex with superfluid helium has been constructed and launched

Complex of the available equipment for UCN source on the WWR-M reactor and a complex of the available experimental installations.

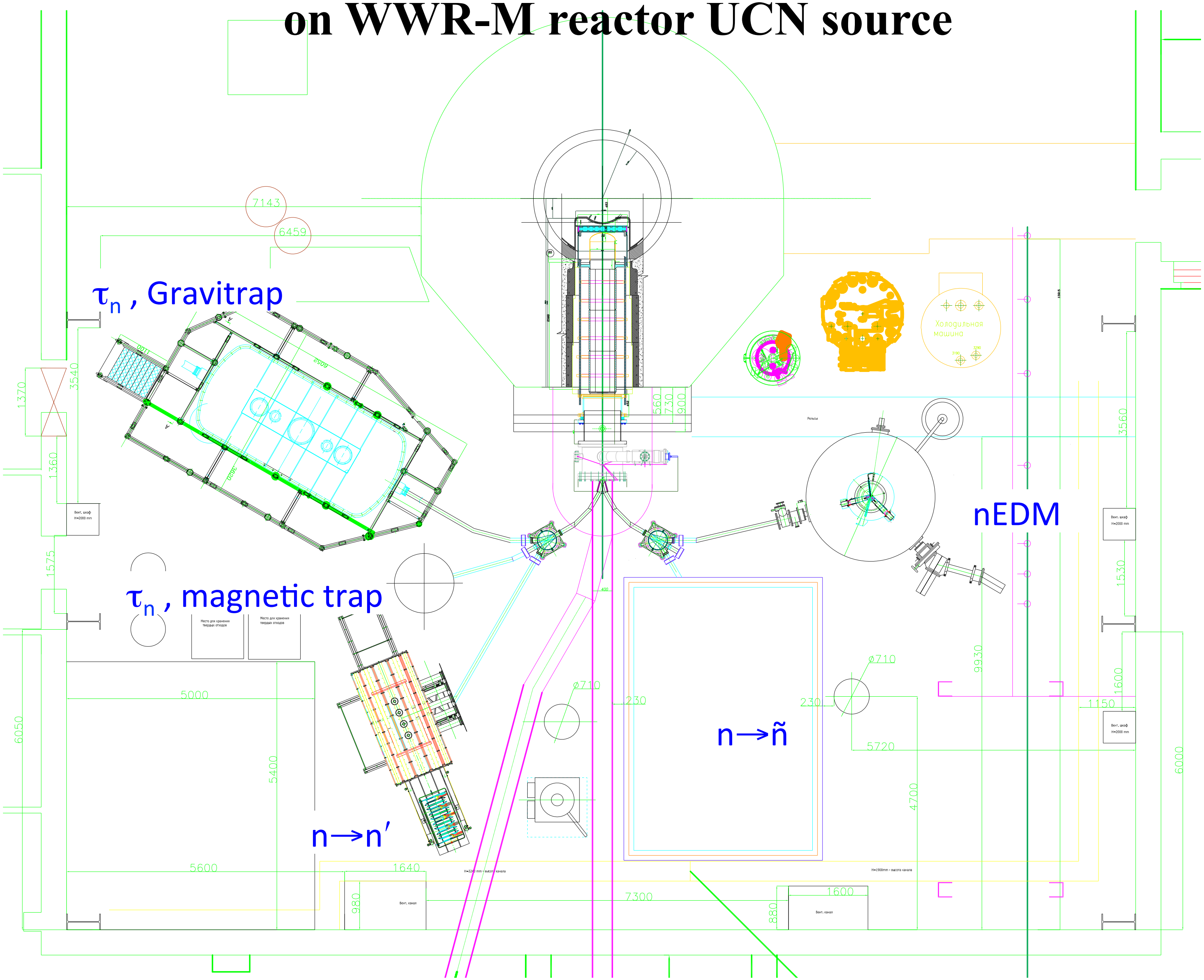


1. WWR-M reactor **2.** Intr-channel part of UCN source in the thermal column of the reactor. **3.** Neutron guide system. **4.** The cryostat for superfluid helium. **5.** He refrigerator on 15K. **6.** He liquefier. **7.** System of vacuum pumping. **8.** Cleaning block He. **9.** Compressor for refrigerator. **10.** Compressor for He liquefier. **11.** He dewar. **12.** He gas-holder. **13.** Downloading compressors He in cylinders. **14.** Balloon cell. **15.** He receivers. **16.** D2 receivers. **17.** Gravitational trap for measurement of neutron lifetime. **18.** EDM spectrometer. **19.** A magnetic trap for measurement of neutron lifetime. **20.** Reflectometer. **21.** Spin-echo a spectrometer with VCN. **22.** Installation for search of mirror dark matter. **23.** WWR-M reactor ramp.

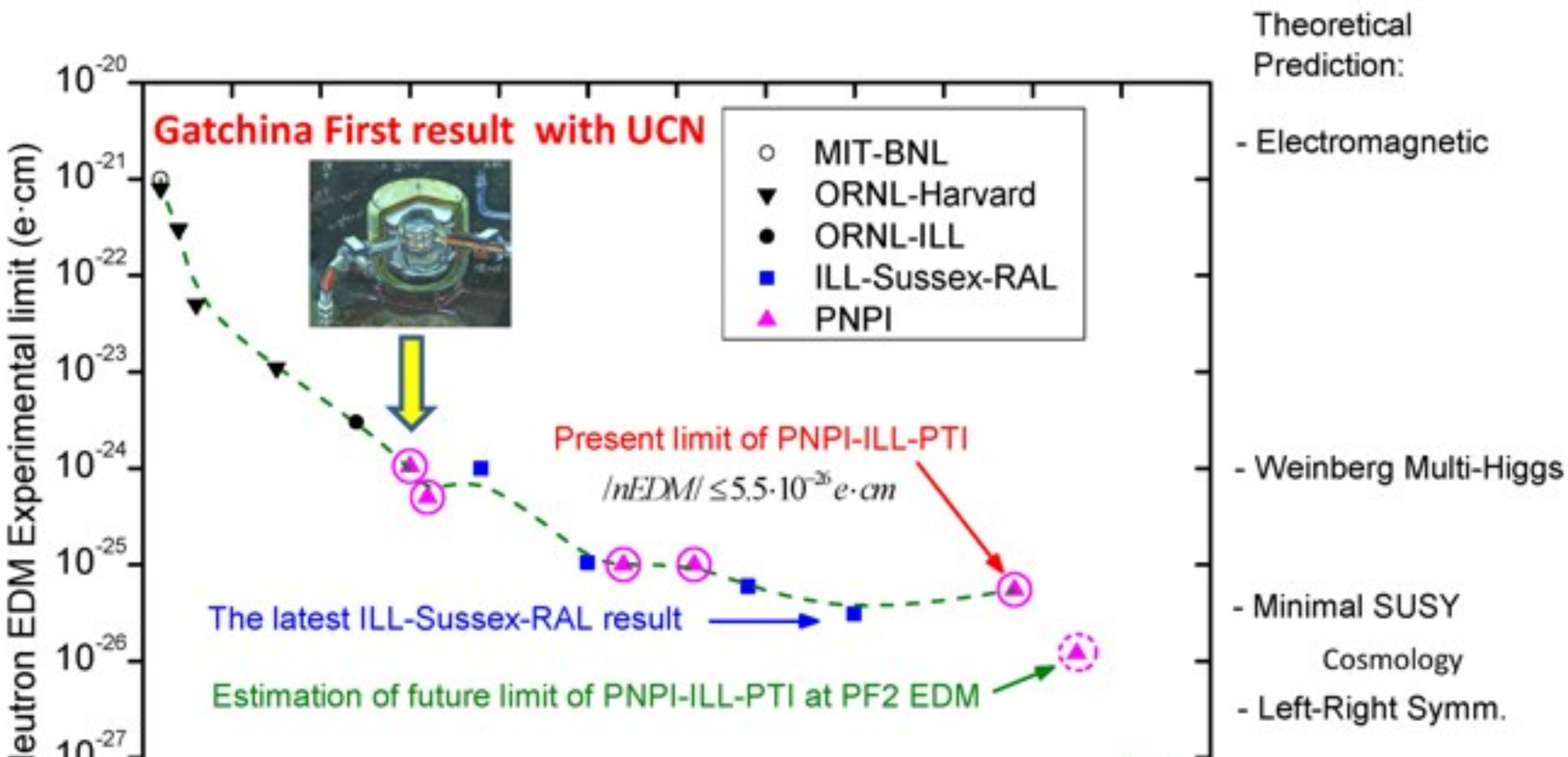
UCN source at WWR-M reactor

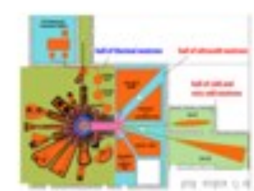
The WWR-M reactor at PNPI is going to be equipped with a high density ultacold neutron source. Method of UCN production is based on their accumulation in the super fluid helium due to particular qualities of that quantum liquid. Our source aims at obtaining a density of UCN up to 10^4 n/cm^3 in the experimental trap, 100 greater then in existing sources presently available in the world.

Experimental installations on WWR-M reactor UCN source



History of nEDM measurements in Gatchina and Grenoble. Result and prospects of PNPI-ILL-PTI collaboration





UCN source at WWR-M reactor

Serebrov. Mainz

Baryon Asymmetry in our Universe

Electroweak SM expectation:

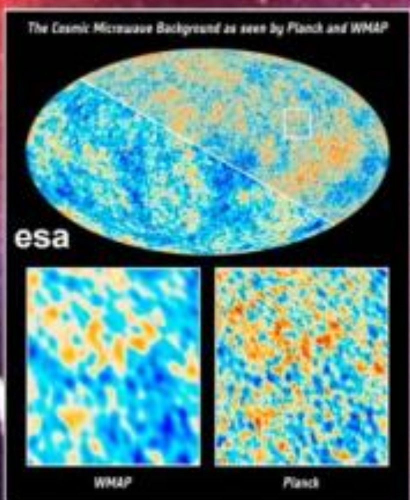
$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-18}$$

vs.

Observed*:

$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 6 \times 10^{-10}$$

Connection between Cosmology and SM of Particle Physics !



Sakharov criteria for Baryogenesis in the early universe:

1. *Baryon number violation*
2. *C and CP violation*
3. *Thermal non-equilibrium*

JETP Lett. 5, 24 (1967)

* e.g. WMAP, COBE, Planck

Thank you for attention