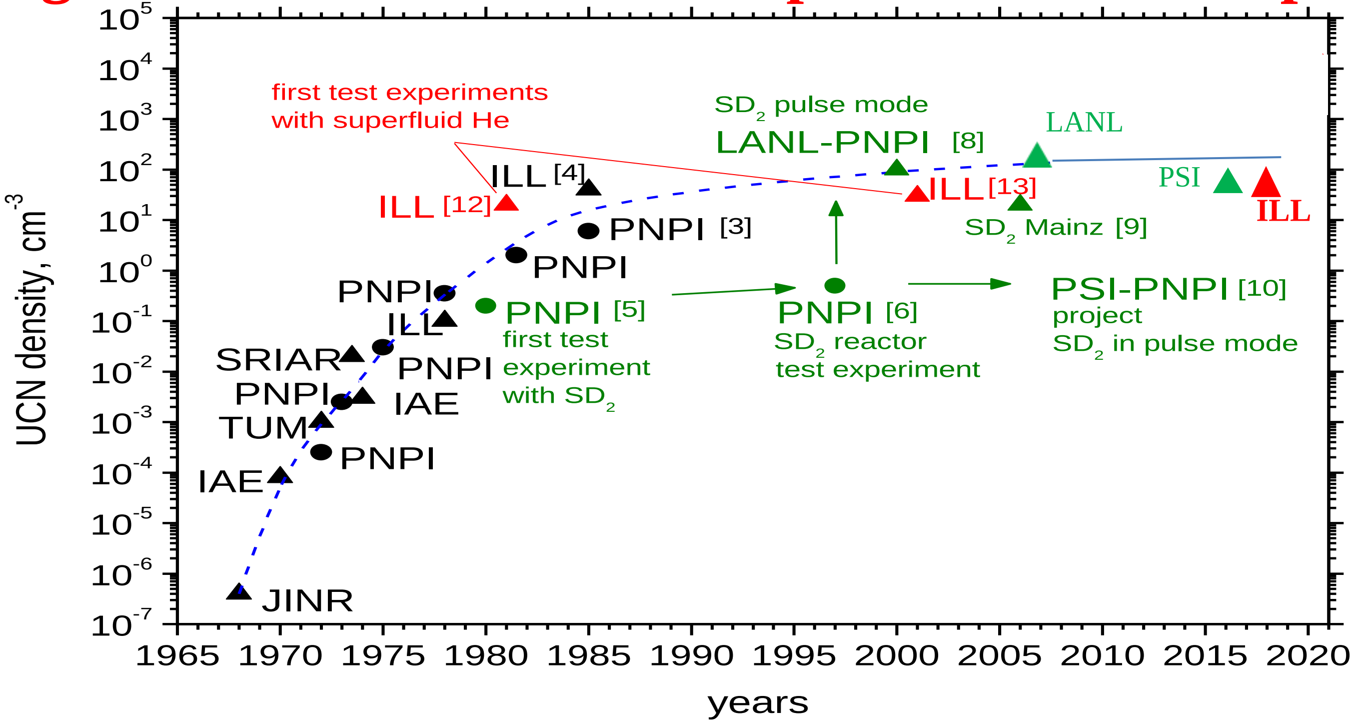
Sources of ultracold neutrons - present status and prospects

- **Development of ultracold neutron sources at PNPI, stages and prospects**
- **Proposal for the ESS neutron complex**

A. Serebrov, NRC KI - PNPI, Gatchina

2. 02. 2022

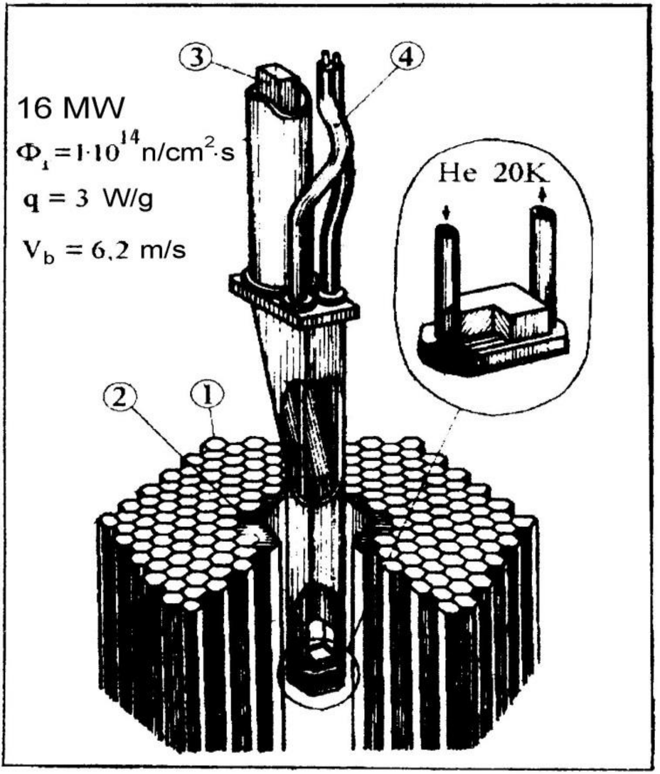
Progress in UCN source development and future prospects



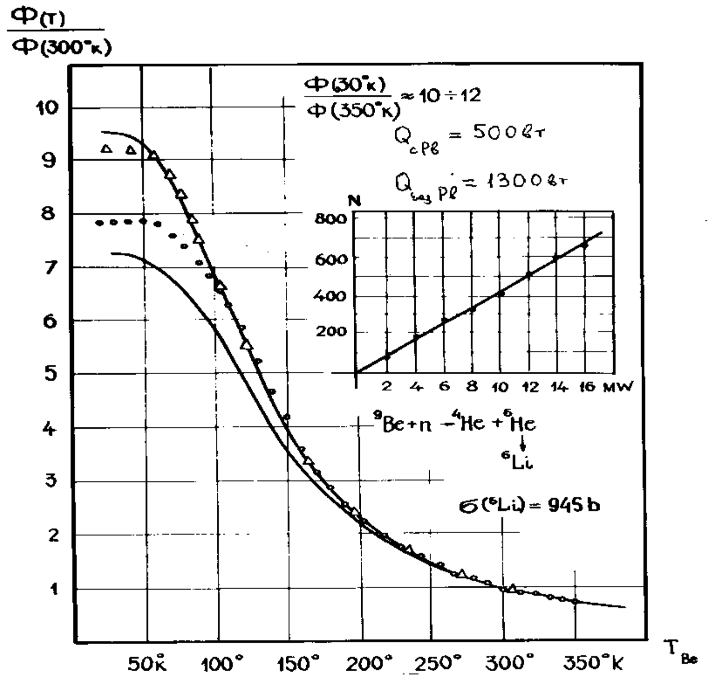
Plot elucidating the progress in UCN source development.

Beryllium UCN source. Gain factor is about 10 times

ucl.Phys., 1980, A341, N2, p.269-283.



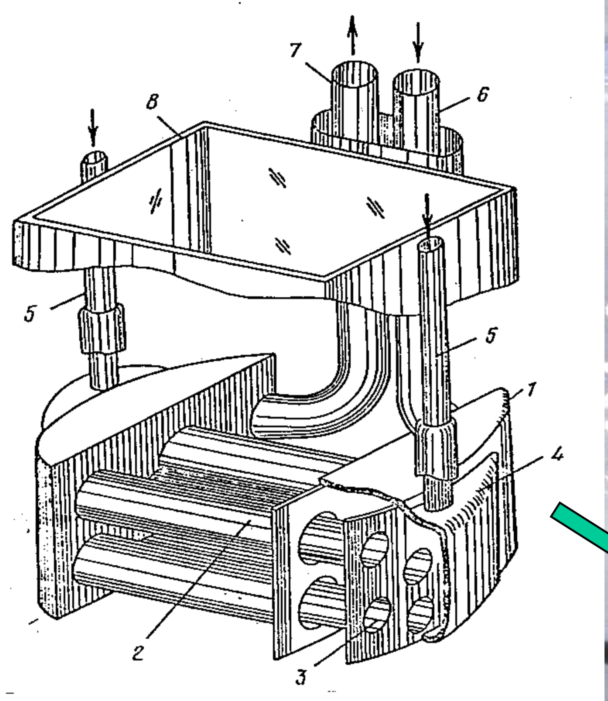
Scheme of a channel with a cooled UCN source in the reactor core. 1 - fuel elements; 2 - lead screen; 3 – mirror neutron guide; 4 – cryo tubes.

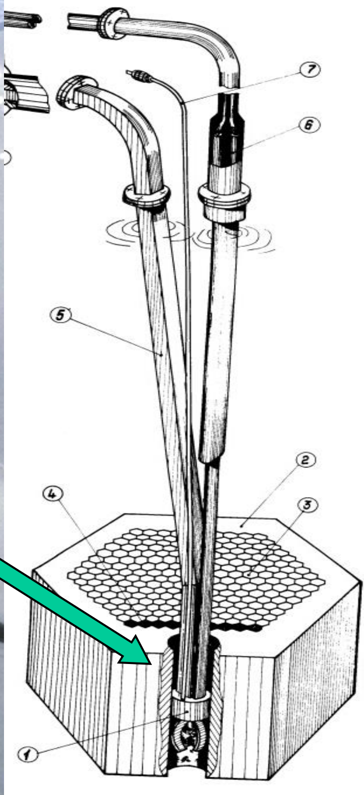


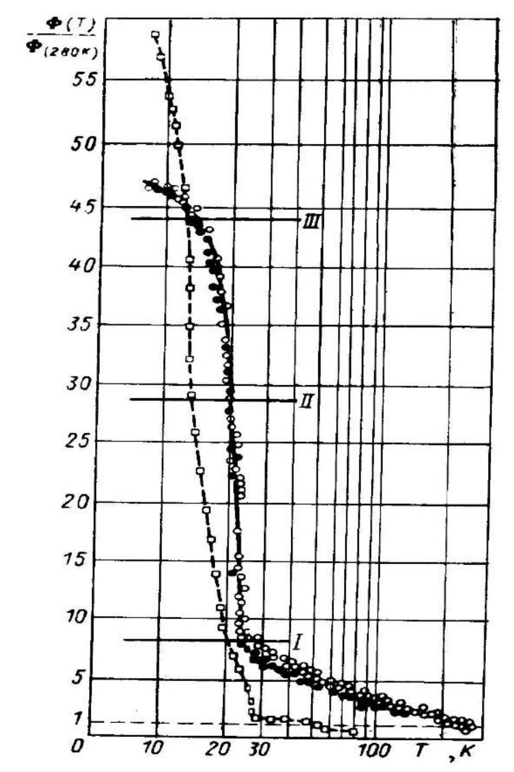
Dependence of the UCN yield on the temperature of the beryllium converter. o – experimental results for the first channel; 👎 - experimental results for the second channel. The solid curves are calculated and indicate the range of possible experimental values. Q is the heat load at reactor power of 16 MW with and without a lead shield.

Small volume hydrogen source (150 cm^3)

Gain factor for H2 is 25 times at 20K and 45 times at 10K. Gain factor for solid D2 have to be considerably more.



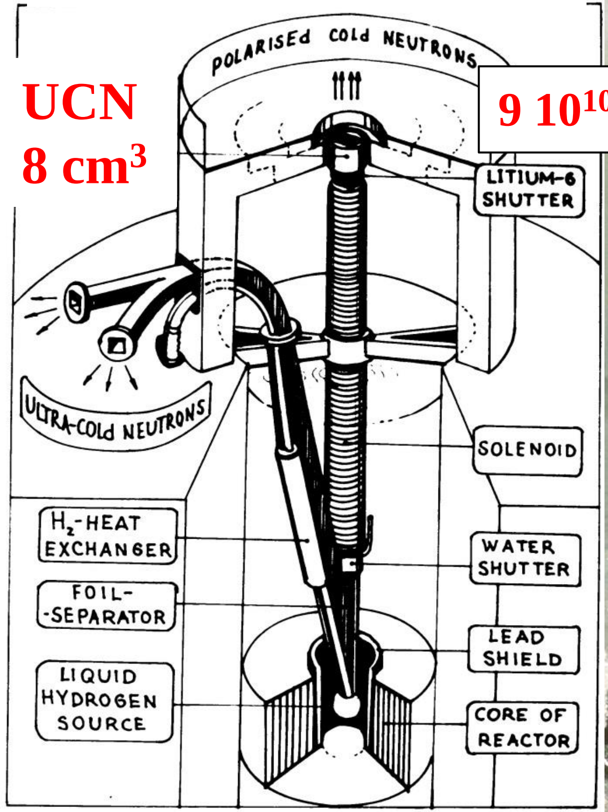




Phys. Lett. A. 1980. V. 80. P. 413

Universal Source of UCN and CN at WWR-M PNPI reactor

Universal cold neutron source

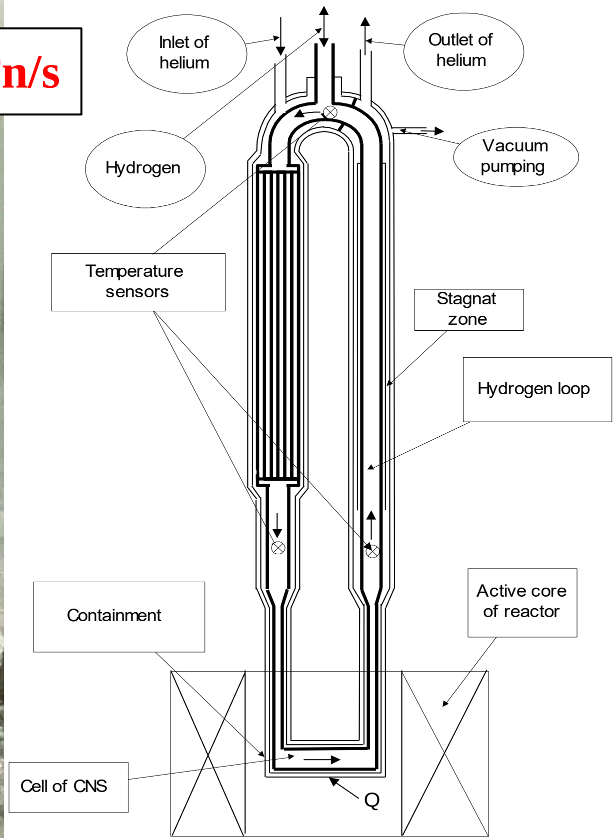


UCN
8 cm^3

9 10^{10}n/s

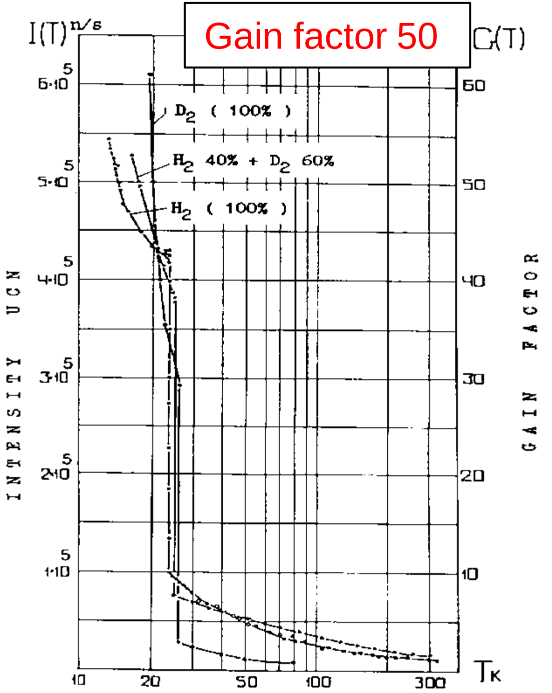
JETP Lett. Vol. 44. No 6. 25 September 1986

Subcooled liquid hydrogen thermosiphon



Gain factors in UCN production at the lower temperature

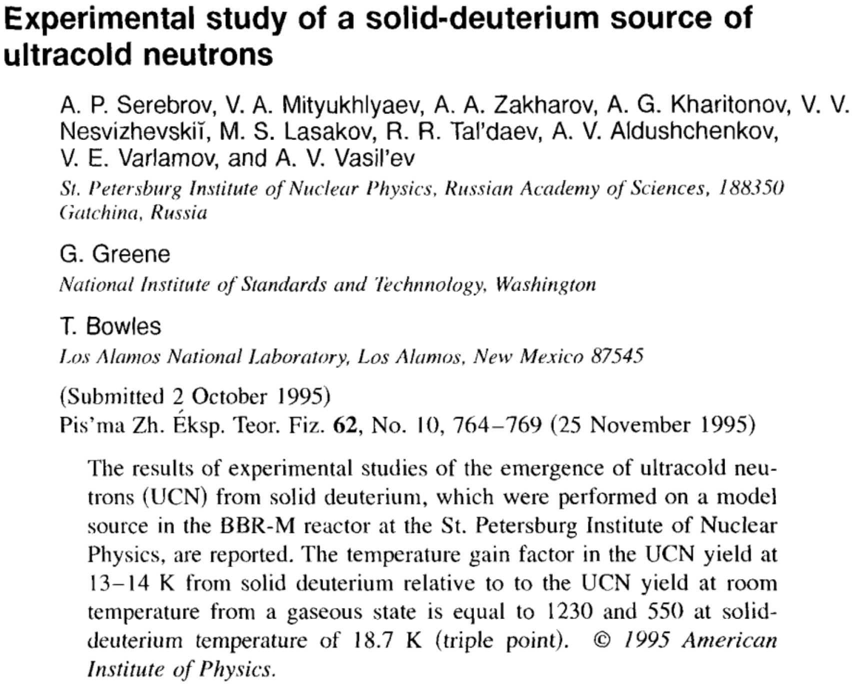
Gain factor 50



Temperature dependence of the yield of ultracold neutrons for different moderators

1995

First demonstration of temperature factor 1200 for solid deuterium in PNPI



Experimental study of a solid-deuterium source of ultracold neutrons

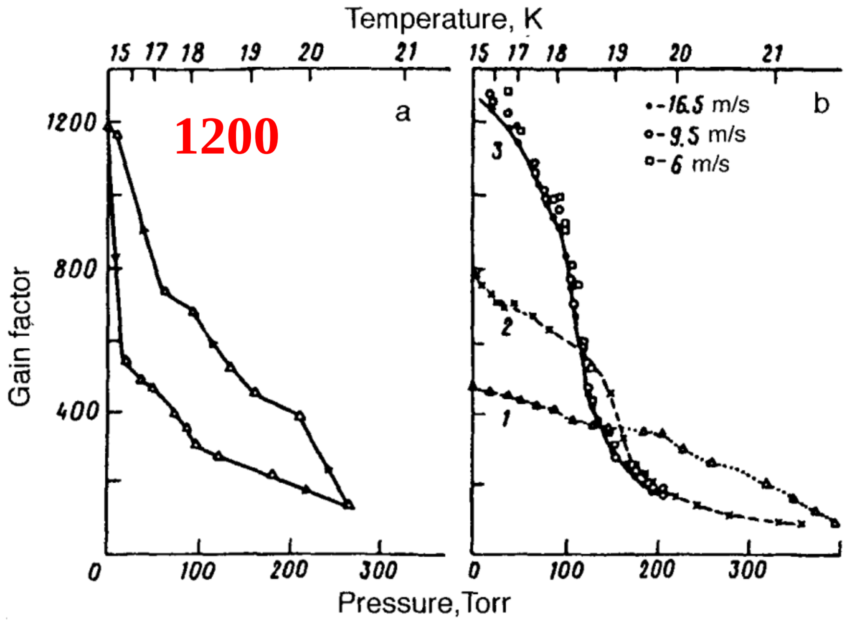
A. P. Serebrov, V. A. Mityukhlyaev, A. A. Zakharov, A. G. Kharitonov, V. V. Nesvizhevskiĭ, M. S. Lasakov, R. R. Tal'daev, A. V. Aldushchenkov, V. E. Varlamov, and A. V. Vasil'ev
St. Petersburg Institute of Nuclear Physics, Russian Academy of Sciences, 188350 Gatchina, Russia

G. Greene
National Institute of Standards and Technnology, Washington

T. Bowles
Los Alamos National Laboratory, Los Alamos, New Mexico 87545

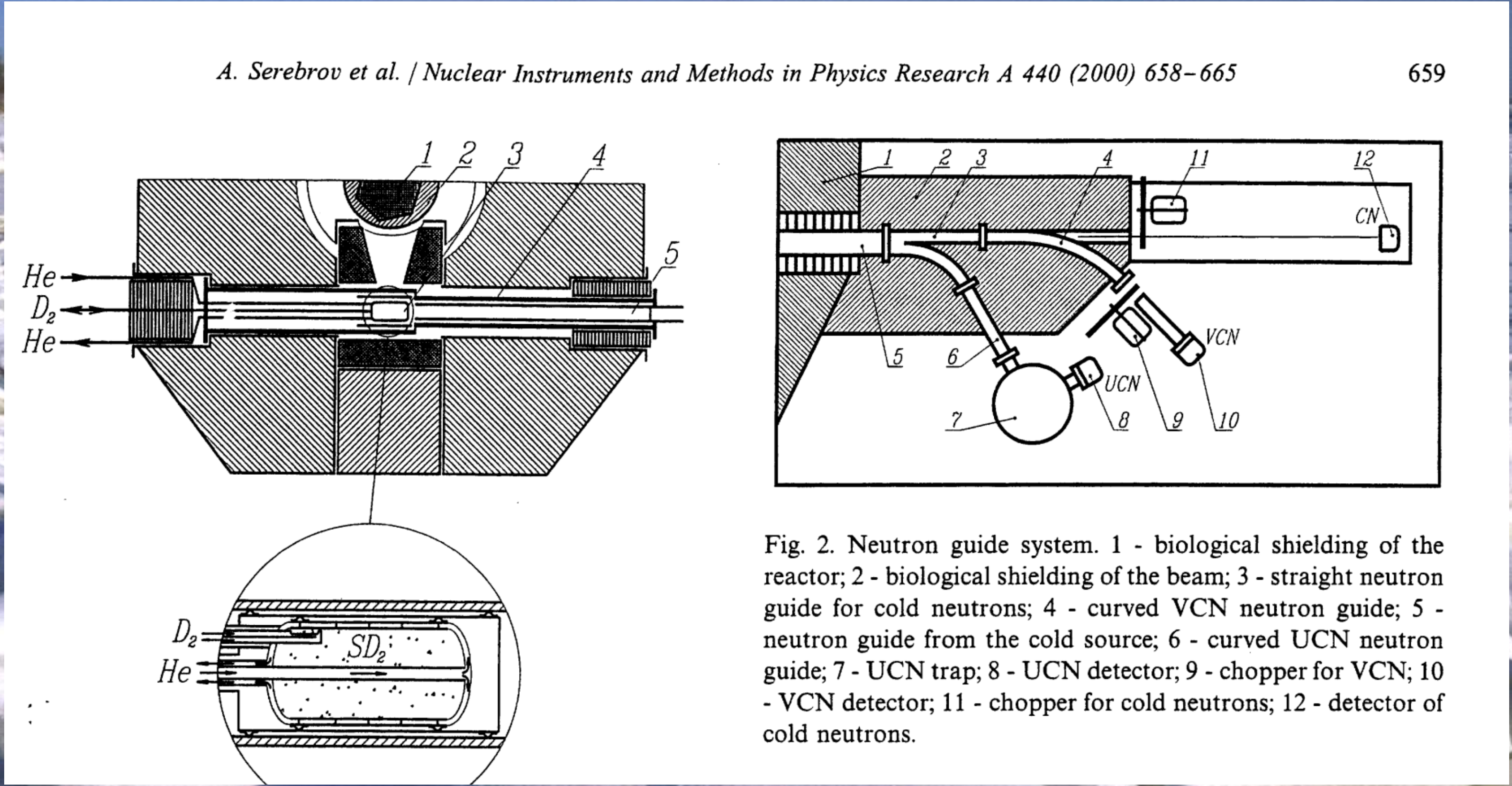
(Submitted 2 October 1995)
Pis'ma Zh. Éksp. Teor. Fiz. **62**, No. 10, 764–769 (25 November 1995)

The results of experimental studies of the emergence of ultracold neutrons (UCN) from solid deuterium, which were performed on a model source in the BBR-M reactor at the St. Petersburg Institute of Nuclear Physics, are reported. The temperature gain factor in the UCN yield at 13–14 K from solid deuterium relative to to the UCN yield at room temperature from a gaseous state is equal to 1230 and 550 at solid-deuterium temperature of 18.7 K (triple point).



JETP Lett., Vol 62. No 25 Nov. 1995

Solid deuterium neutron source for UCN production

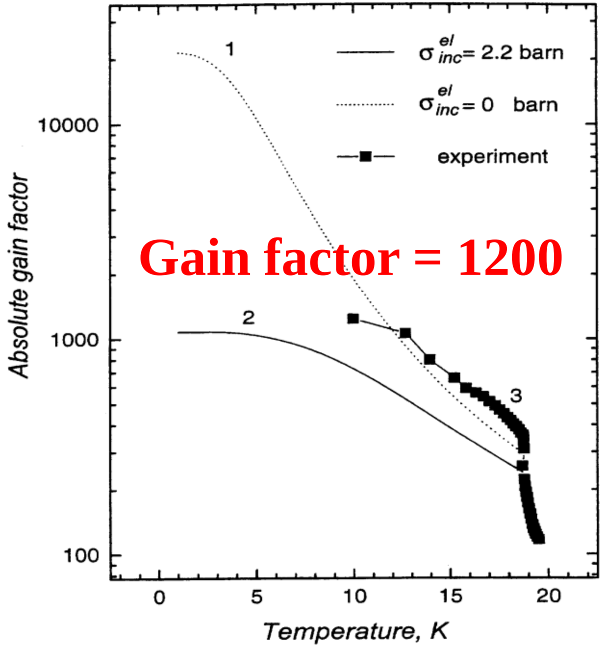


A. Serebrov et al. / Nuclear Instruments and Methods in Physics Research A 440 (2000) 658–665 659

Fig. 2. Neutron guide system. 1 - biological shielding of the reactor; 2 - biological shielding of the beam; 3 - straight neutron guide for cold neutrons; 4 - curved VCN neutron guide; 5 - neutron guide from the cold source; 6 - curved UCN neutron guide; 7 - UCN trap; 8 - UCN detector; 9 - chopper for VCN; 10 - VCN detector; 11 - chopper for cold neutrons; 12 - detector of cold neutrons.

Studies of a solid-deuterium source for ultracold neutrons. // Nucl. Instr. Meth., 2000, V.A440, P.658-666.

Gain factor of Solid deuterium UCN source



Gain factor = 1200

Fig. 8. The temperature dependence of the absolute gain factor (see text) of the deuterium source.

Additional gain factor with respect to liquid D2

UCN

VCN

CN

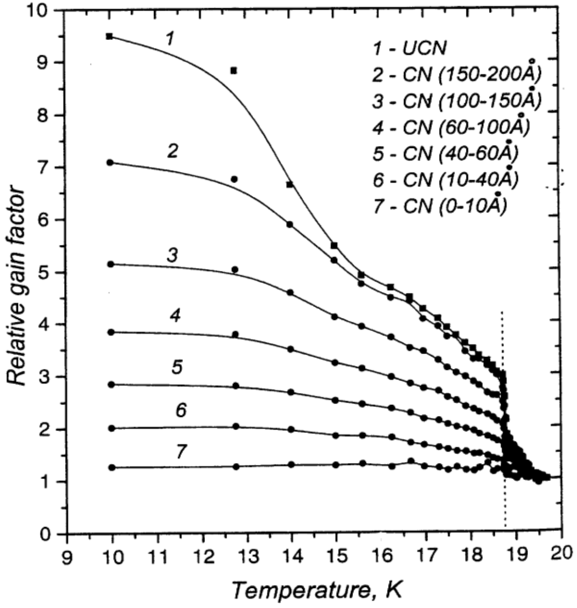


Fig. 6. The relative gain factor for neutrons of different wavelength ranges as a function of the temperature.

Studies of a solid-deuterium source for ultracold neutrons. // Nucl. Instr. Meth., 2000, V.A440, P.658-666.

Gain factor of Solid deuterium UCN source

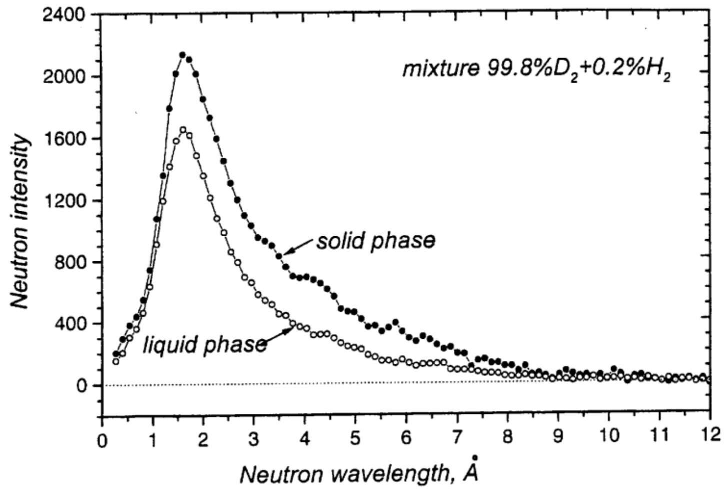


Fig. 3. Spectra of cold neutrons for solid and liquid phases of the deuterium.

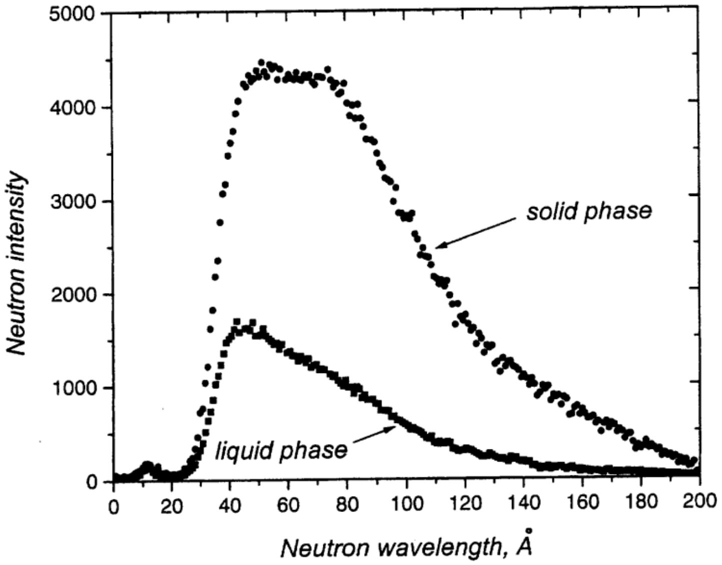


Fig. 4. Spectra of very cold neutrons for solid and liquid phases of the deuterium.

Studies of a solid-deuterium source for ultracold neutrons. // Nucl. Instr. Meth., 2000, V.A440, P.658-666

Problems with Solid deuterium UCN source

Transmission test

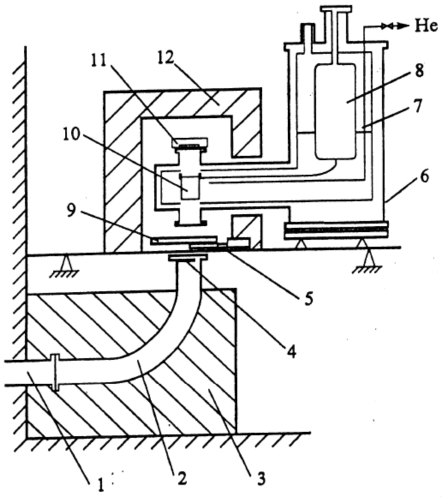


Fig.1. Experimental setup: *1* – horizontal neutron guide; *2* – bent mirror neutron guide; *3* – combined protection; *4* – cadmium mask; *5* – monitor detector; *6* – target-cryostat; *7* – liquid nitrogen tank; *8* – helium tank; *9* – neutron beam chopper; *10* – deuterium vessel; *11* – main neutron detector; *12* – polyethylene shielding

Crystal structure. Cooling process

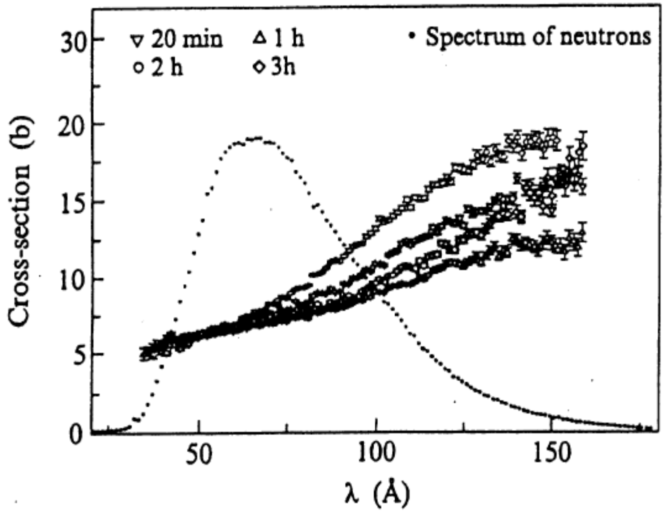


Fig.2. Cross-section as a function of neutron wavelength for deuterium with a concentration of the ortho-phase (93 ± 3)% and for different time of freezing

Orto-para concentration

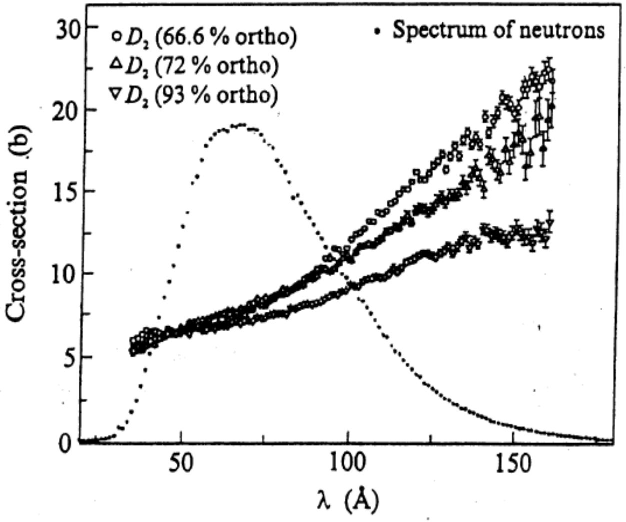


Fig.3. Cross-section as a function of neutron wavelength for different ortho-para ratios and for the same time of freezing – 2 hours

JETP LETTERS Vol. 74 No. 6 2001

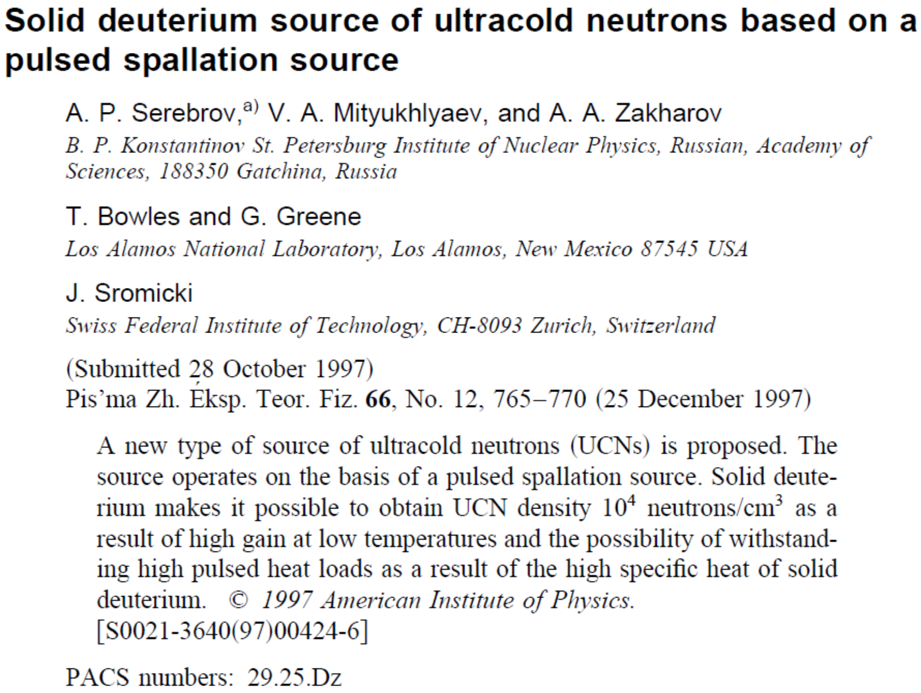
Neutron Parameters of the PNPI sources

Parameter	Value			
	CBS	**SLHS**	**UCNS**	**SDS**
Moderator substance	**Be**	**Hydrogen**	**Mixture 40% H_2 60% D_2**	**Deuterium**
Thermal neutrons flux at 18 MW $n\cdot cm^{-2}\cdot s^{-1}$	**$1.0*10^{14}$**	**$6*10^{13}$**	**$(1,5-2.0)*10^{14}$**	**$1.7*10^{12}$**
Fast neutrons flux with E>1MeV $n\cdot cm^{-2}\cdot s^{-1}$	–	**$8.0*10^{12}$**	**$2.0*10^{13}$**	**$\sim 3.0*10^{9}$**
Intensity n/s UCN (CN)	**$2*10^{4}$**	**$4*10^{4}$**	**$(3-5)*10^{5}$; $(9*10^{10})$**	**-**
CN flux ; $n\cdot cm^{-2}\cdot s^{-1}$	**-**	**-**	**$1.8*10^{9}$**	**-**
UCN flux; $n\cdot cm^{-2}\cdot s^{-1}$	**$5*10^{2}$**	**$1*10^{3}$**	**$6*10^{3}$**	**-**
Gain factor UCN(CN)	**12**	**30**	**30-45(50)**	**1230**

- **CBS – Cold Beryllium Source**
- **SLHS – Small Liquid Hydrogen Source**
- **UCNS – Universal Cold Neutron Source**
- **SDS – Solid Deuterium Source**

1997

Proposal to use pulse mode with spallation target



Solid deuterium source of ultracold neutrons based on a pulsed spallation source

A. P. Serebrov,[a)] V. A. Mityukhlyaev, and A. A. Zakharov
B. P. Konstantinov St. Petersburg Institute of Nuclear Physics, Russian, Academy of Sciences, 188350 Gatchina, Russia

T. Bowles and G. Greene
Los Alamos National Laboratory, Los Alamos, New Mexico 87545 USA

J. Sromicki
Swiss Federal Institute of Technology, CH-8093 Zurich, Switzerland

(Submitted 28 October 1997)
Pis'ma Zh. Éksp. Teor. Fiz. **66**, No. 12, 765–770 (25 December 1997)

A new type of source of ultracold neutrons (UCNs) is proposed. The source operates on the basis of a pulsed spallation source. Solid deuterium makes it possible to obtain UCN density 10^4 neutrons/cm^3 as a result of high gain at low temperatures and the possibility of withstanding high pulsed heat loads as a result of the high specific heat of solid deuterium. © *1997 American Institute of Physics.* [S0021-3640(97)00424-6]

PACS numbers: 29.25.Dz

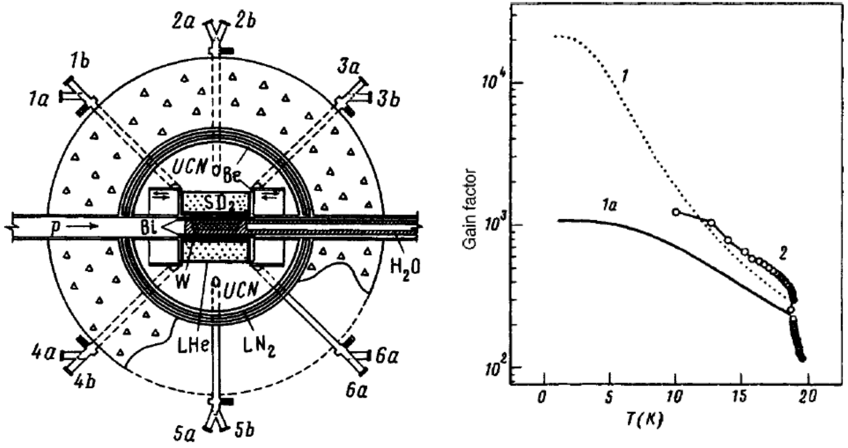
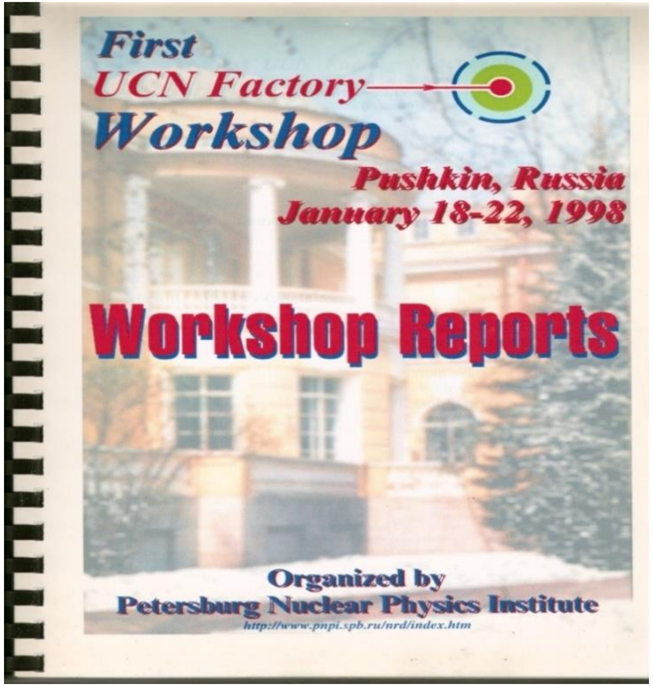


FIG. 2. Temperature gain of UCN yield for solid deuterium normalized to the UCN yield at room temperature: *1* — Computed curve for a large source with incoherent elastic scattering cross section of UCNs equal to zero or for a UCN source in the accumulation mode; *1a* — computed curve for a large source taking account of UCN scattering (2.2 b) and the hydrogen impurity (0.2%); *2* — experimental results obtained on a reactor with a source volume of 6 liters of solid deuterium containing 0.2% hydrogen. The large increase in the UC yield at 18.7 K is due to a transition from the liquid to the solid state.

JETP Letters 66 (1997) 802

Our proposal for SD2 UCN source

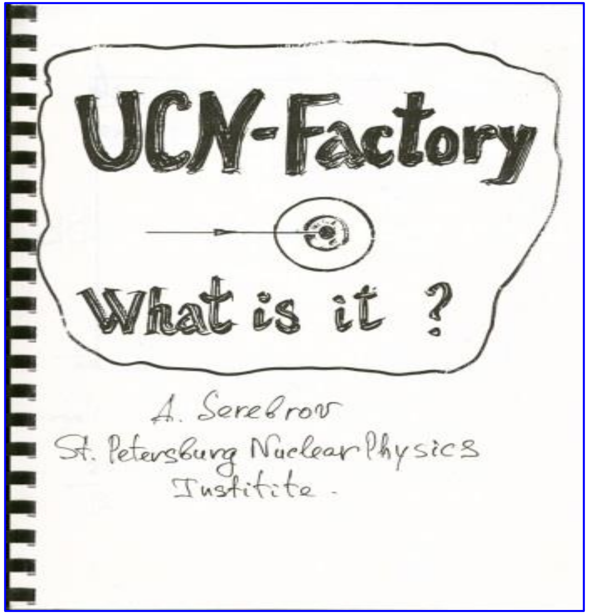
24 years ago



First
UCN Factory
Workshop
Pushkin, Russia
January 18-22, 1998

Workshop Reports

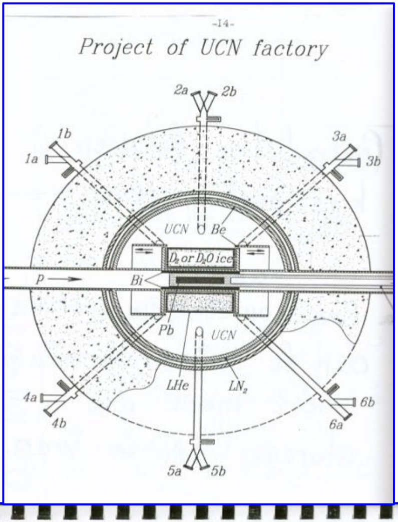
Organized by
Petersburg Nuclear Physics Institute
http://www.pnpi.spb.ru/nrd/index.htm



UCN-Factory

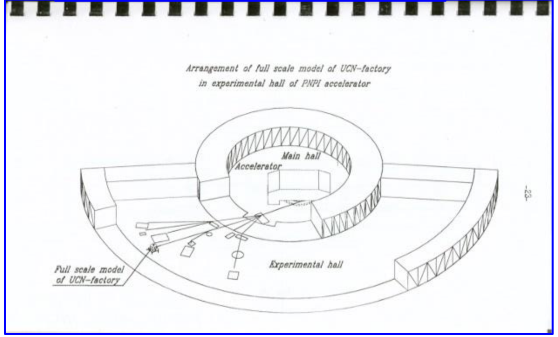
What is it ?

A. Serebrov
St. Petersburg Nuclear Physics
Institute.



-14-

Project of UCN factory



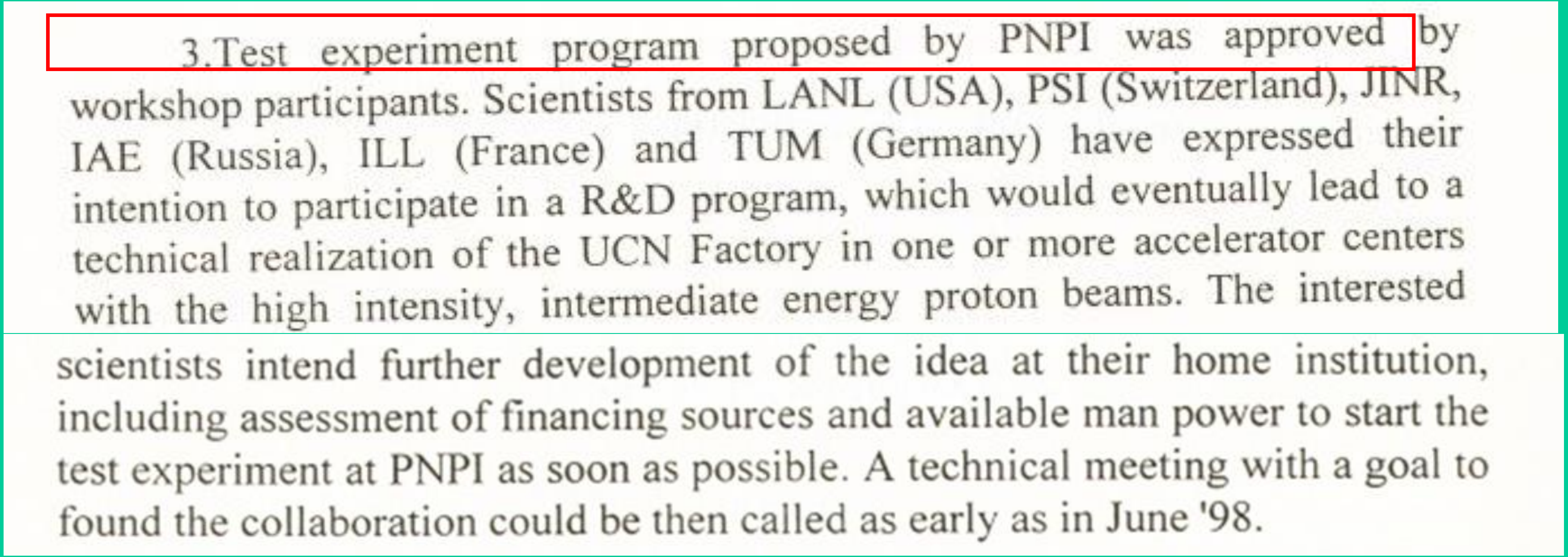
Arrangement of full scale model of UCN-factory
in experimental hall of PNPI accelerator

-23-

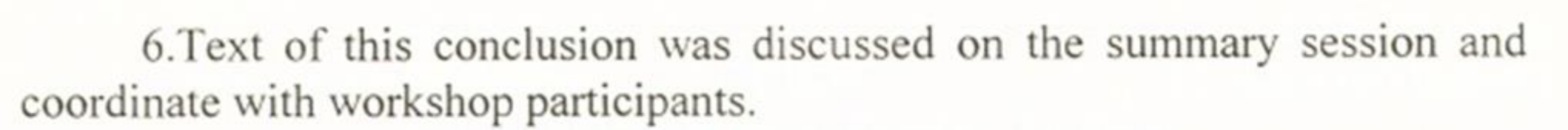
Solid deuterium source of ultracold neutrons on a pulsed source. // *JETP Letters 66 (1997) 802*

Serebrov A.P. Solid deuterium and UCN factory: Nucl. Instr. Meth., 2000, V.A440, P.653-657.

Conclusion

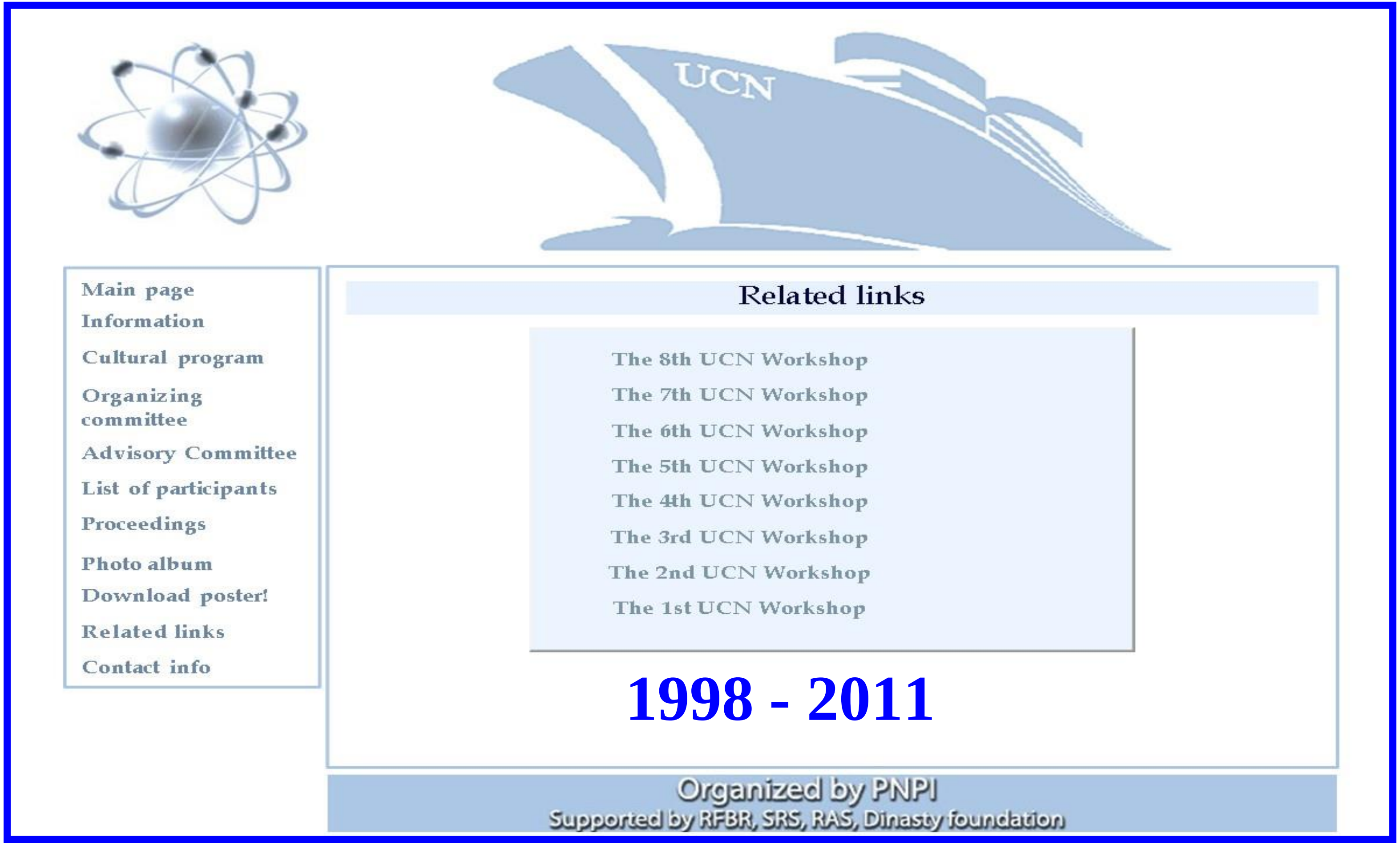


3.Test experiment program proposed by PNPI was approved by workshop participants. Scientists from LANL (USA), PSI (Switzerland), JINR, IAE (Russia), ILL (France) and TUM (Germany) have expressed their intention to participate in a R&D program, which would eventually lead to a technical realization of the UCN Factory in one or more accelerator centers with the high intensity, intermediate energy proton beams. The interested scientists intend further development of the idea at their home institution, including assessment of financing sources and available man power to start the test experiment at PNPI as soon as possible. A technical meeting with a goal to found the collaboration could be then called as early as in June '98.



6.Text of this conclusion was discussed on the summary session and coordinate with workshop participants.

January 22 1998 Pushkin



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Related links

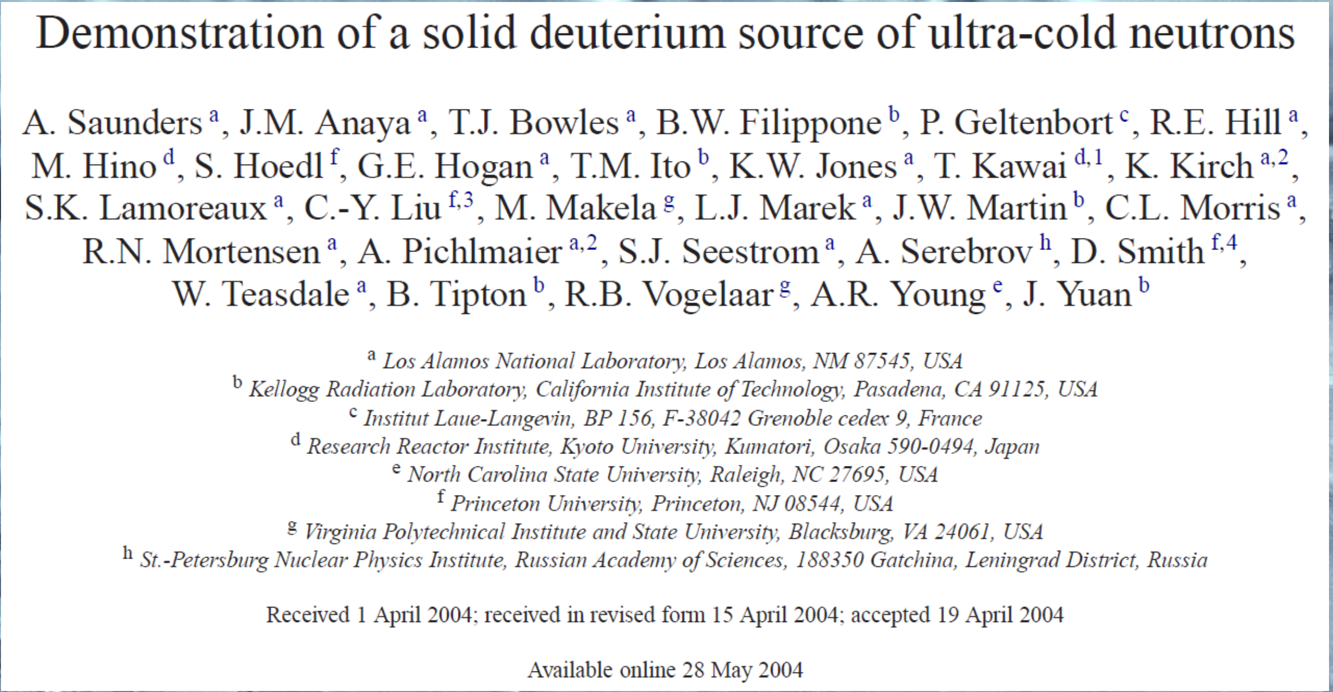
- The 8th UCN Workshop
- The 7th UCN Workshop
- The 6th UCN Workshop
- The 5th UCN Workshop
- The 4th UCN Workshop
- The 3rd UCN Workshop
- The 2nd UCN Workshop
- The 1st UCN Workshop

1998 - 2011

Organized by PNPI
Supported by RFBR, SRS, RAS, Dinasty foundation

A few photos

The use of solid deuterium UCN source in LANL

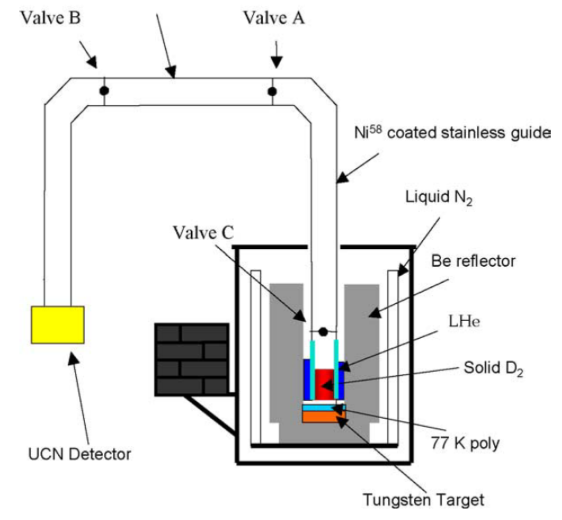


Demonstration of a solid deuterium source of ultra-cold neutrons

A. Saunders [a], J.M. Anaya [a], T.J. Bowles [a], B.W. Filippone [b], P. Geltenbort [c], R.E. Hill [a], M. Hino [d], S. Hoedl [f], G.E. Hogan [a], T.M. Ito [b], K.W. Jones [a], T. Kawai [d,1], K. Kirch [a,2], S.K. Lamoreaux [a], C.-Y. Liu [f,3], M. Makela [g], L.J. Marek [a], J.W. Martin [b], C.L. Morris [a], R.N. Mortensen [a], A. Pichlmaier [a,2], S.J. Seestrom [a], A. Serebrov [h], D. Smith [f,4], W. Teasdale [a], B. Tipton [b], R.B. Vogelaar [g], A.R. Young [e], J. Yuan [b]

[a] *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[b] *Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, CA 91125, USA*
[c] *Institut Laue-Langevin, BP 156, F-38042 Grenoble cedex 9, France*
[d] *Research Reactor Institute, Kyoto University, Kumatori, Osaka 590-0494, Japan*
[e] *North Carolina State University, Raleigh, NC 27695, USA*
[f] *Princeton University, Princeton, NJ 08544, USA*
[g] *Virginia Polytechnical Institute and State University, Blacksburg, VA 24061, USA*
[h] *St.-Petersburg Nuclear Physics Institute, Russian Academy of Sciences, 188350 Gatchina, Leningrad District, Russia*

Received 1 April 2004; received in revised form 15 April 2004; accepted 19 April 2004



This source produced bottled UCN densities of **145 ±7 UCN/cm$_3$,** about three times greater than the largest bottled UCN densities previously reported.

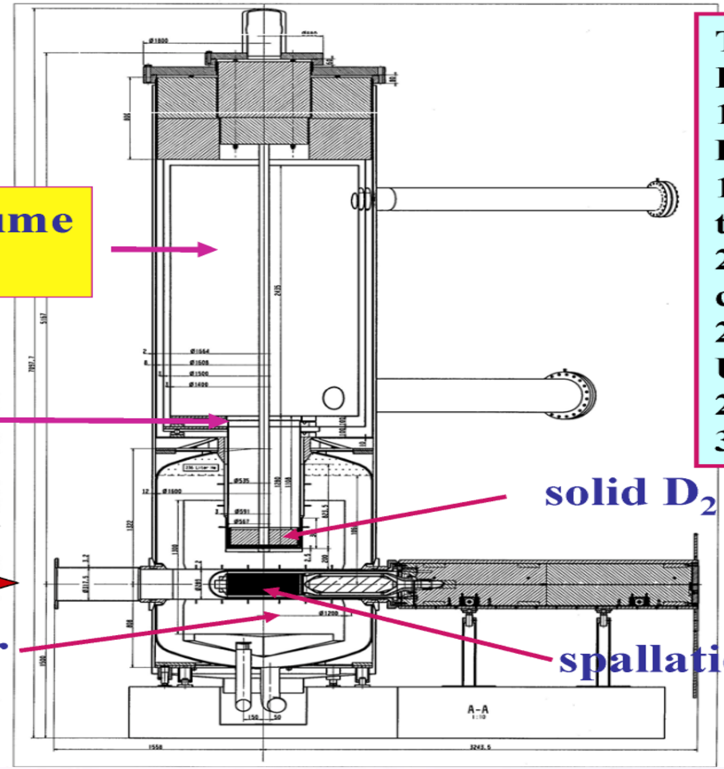
sD2 source – 34 cm^{-3}

Polarized In the EDM trap

2018

Solid deuterium UCN source at PSI (PNPI-PSI project)

UCN density – 34 cm^{-3}



UCN storage volume $2m^3$

UCN shutter

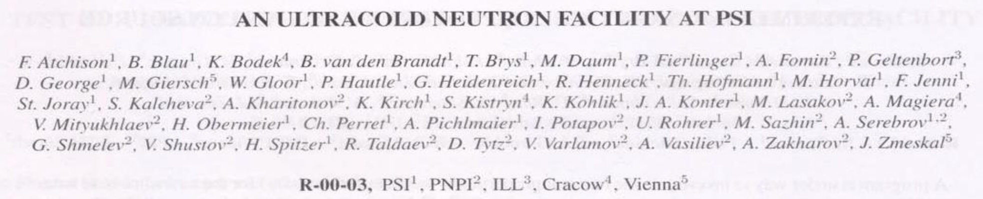
solid D_2 moderator

p beam

D_2O moderator

spallation target

$T_p = 600MeV$
$I_p = 2mA$
10n/p
Per pulse:
$10^{17}p \rightarrow 10^{18}n$
thermal flux:
$2 \cdot 10^{14}\ s^{-1}\ cm^{-2}$
cold flux:
$2 \cdot 10^{13}\ s^{-1}\ cm^{-2}$
UCN:
$2 \cdot 10^{5}\ s^{-1}\ cm^{-3}$
$3 \cdot 10^{3}\ cm^{-3}$ stored



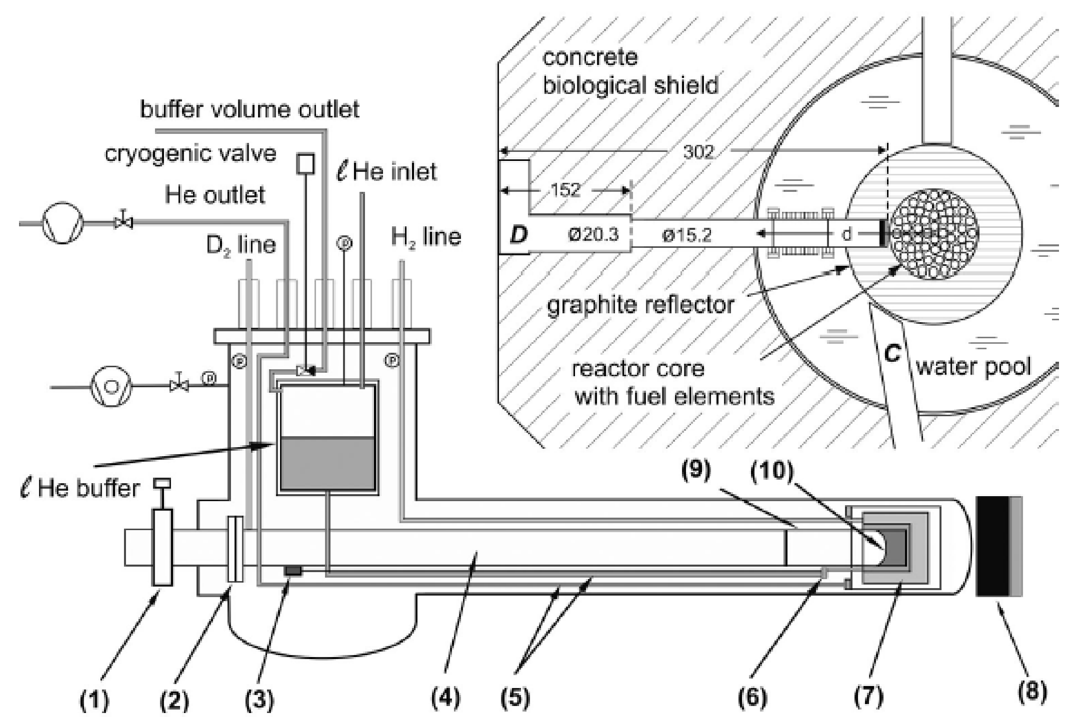
AN ULTRACOLD NEUTRON FACILITY AT PSI

F. Atchison[1], B. Blau[1], K. Bodek[4], B. van den Brandt[1], T. Brys[1], M. Daum[1], P. Fierlinger[1], A. Fomin[2], P. Geltenbort[3], D. George[1], M. Giersch[5], W. Gloor[1], P. Hautle[1], G. Heidenreich[1], R. Henneck[1], Th. Hofmann[1], M. Horvat[1], F. Jenni[1], St. Joray[1], S. Kalcheva[2], A. Kharitonov[2], K. Kirch[1], S. Kistryn[4], K. Kohlik[1], J. A. Konter[1], M. Lasakov[2], A. Magiera[4], V. Mityukhlaev[2], H. Obermeier[1], Ch. Perret[1], A. Pichlmaier[1], I. Potapov[2], U. Rohrer[1], M. Sazhin[2], A. Serebrov[1,2], G. Shmelev[2], V. Shustov[2], H. Spitzer[1], R. Taldaev[2], D. Tytz[2], V. Varlamov[2], A. Vasiliev[2], A. Zakharov[2], J. Zmeskal[5]

R-00-03, PSI[1], PNPI[2], ILL[3], Cracow[4], Vienna[5]

The TRIGA Mainz UCN source

sD2 source – 10 cm^{-3}



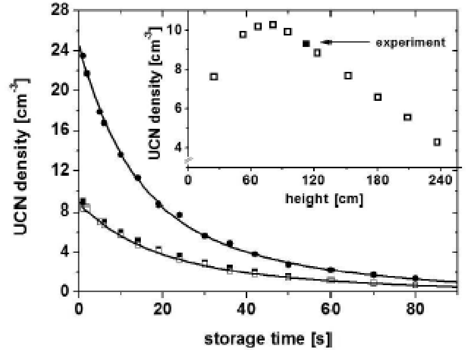
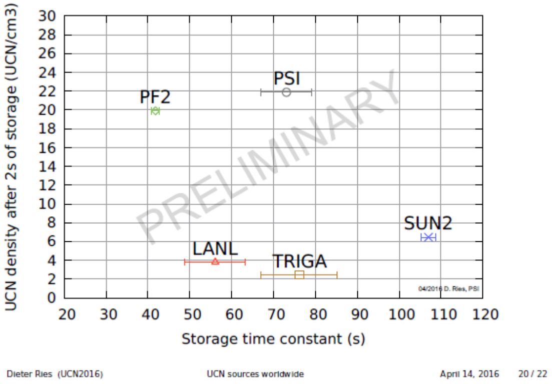


Fig. 8. Expected UCN densities (hollow squares) per reactor pulse of 10 MJ in the storage vessel of $V_{st}^{II} = 9.5$ L plotted as a function of the storage time T_{st} for *Conf-I*. To get a better comparison, the experimental data of fig. 6 are also shown in the diagram (full squares). From extrapolation $T_{st} \to 0$, one derives a UCN density of $8.8/\text{cm}^3$, which is somewhat less than the experimental value of $\rho_{ucn}(0) = 9.4 \pm 0.2/\text{cm}^3$. A bi-exponential fit to the measured and simulated data within the error bars give the same numbers for the characteristic time constants, namely $\tau_1 \approx 14$ s and $\tau_2 \approx 40$ s. MC simulations (full circles) using ^{58}NiMo-coated stainless-steel tubes with a factor of two lower diffuse reflection compared to Nocado predict a UCN density ($T_{st} \to 0$) of about $25/\text{cm}^3$. Inset: MC simulation of the expected UCN densities ($T_{st} \to 0$) for *Conf-I* ($V_{st}^{II} = 9.5$ L) as a function of the height Δh of the storage setup above the exit of the source.

PHYSICAL REVIEW C 95, 045503 (2017)



PHYSICAL REVIEW C **95**, 045503 (2017)

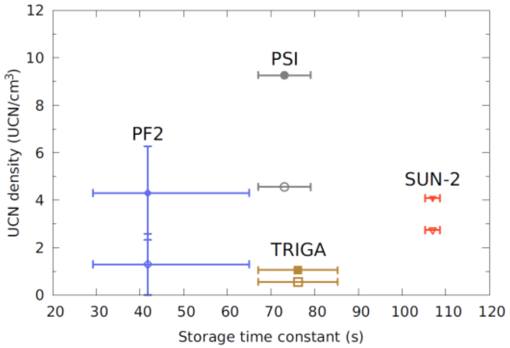


FIG. 31. Measured largest UCN densities in the standard storage bottle after a storage time of 50 s (filled symbols) and 100 s (open symbols) at a given UCN source, plotted versus the measured storage time constant. The measurement conditions are explained in the text and we use the same measurements as shown in Fig. 29. Due to the leakage issues as discussed in the PF2 section a considerable leakage subtraction had to be applied to the counts shown in Fig. 12.

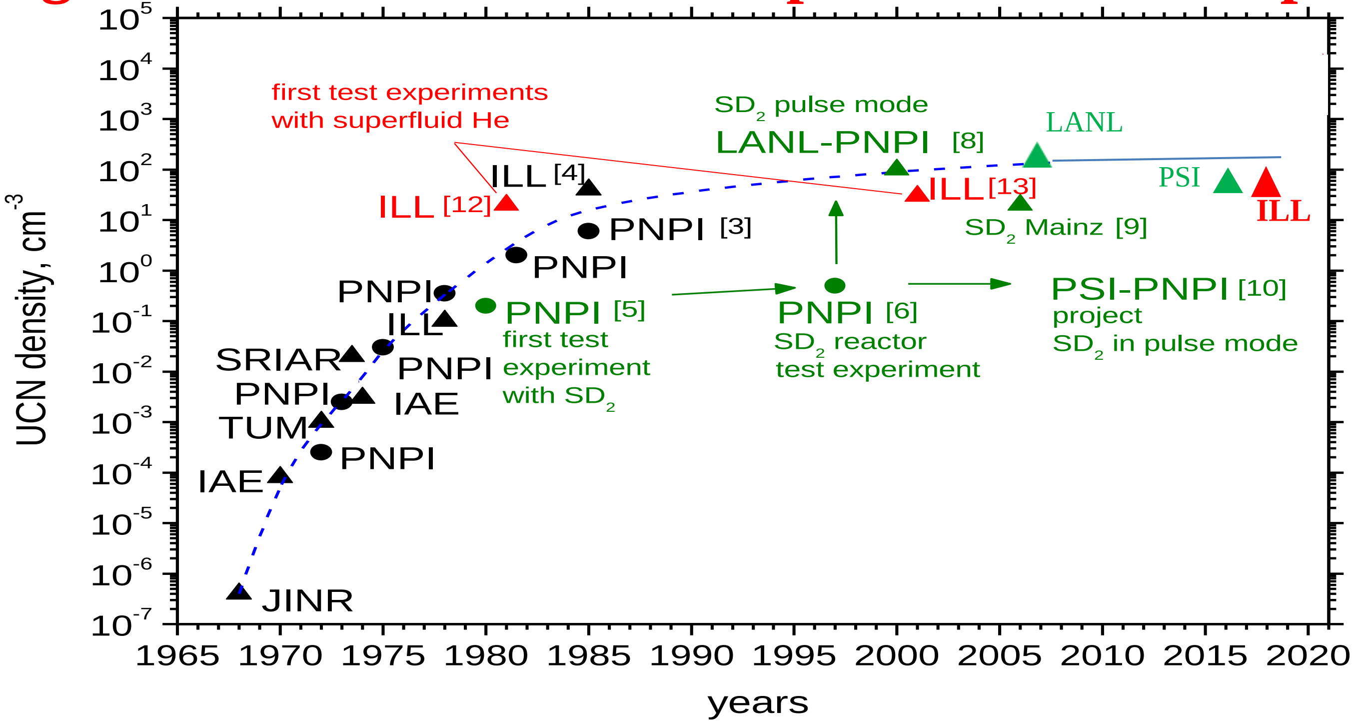
PF2@ILL, Grenoble, France - Aug 2015

Original position of the nEDM experiment now taking data at PSI.

Progress over 5 years

	Status for 2016	Progress over 5 years	Status for 2021
ILL	Turbine source – 20 cm^{-3} He source – prototype	He source under construction (200 cm^{-3})	Turbine source – 20 cm^{-3} SUN2 has produced a record in-situ density of 220 cm^{-3} with no corrections applied to the extraction measurement.
TRIUMF	He source under construction	2017 – UCN prototype installed 2018 – First UCN produced) 2021 – Uninstallation 2022 – UCN source installation (300 cm^{-3})	The corresponding UCN density in the whole production and guide volume (60.8 liters) was 5.3 cm^{-3}
PSI	sD2 source – 22 cm^{-3}	Cryogenics upgrade sD2 structure improved	UCN density – 34 cm^{-3}
TRIGA	sD2 source – 3 cm^{-3}		sD2 source – 10 cm^{-3}
LANL	sD2 source – 145 cm^{-3}	Optimization of cryostat and moderator geometry Replaceable moderator New flapper valve design Modify UCN tee	sD2 source – 39 cm^{-3} Polarized In EDM trap
FRM II		The UCN source is still in the construction	

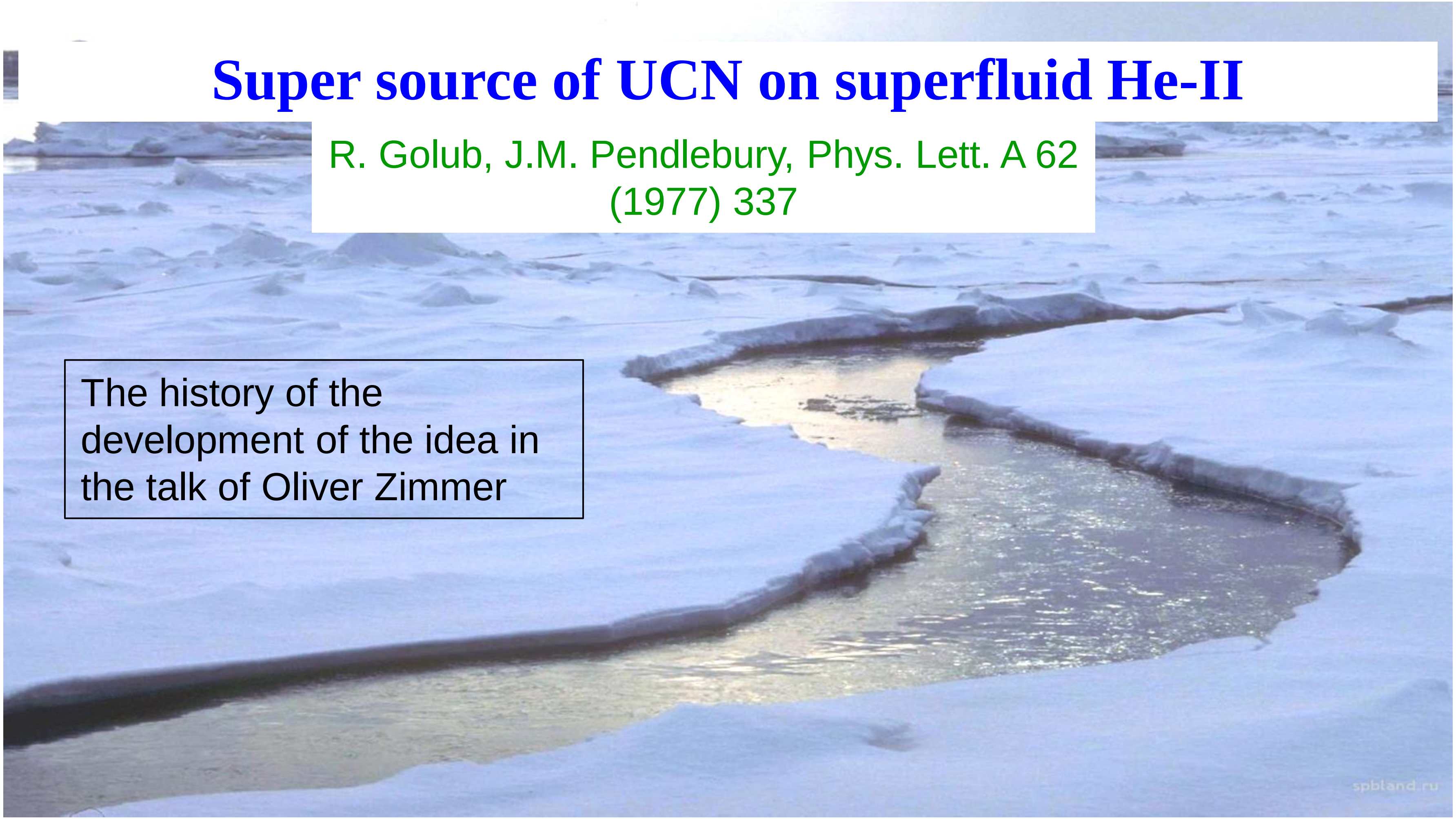
Progress in UCN source development and future prospects



Plot elucidating the progress in UCN source development.

Super source of UCN on superfluid He-II

R. Golub, J.M. Pendlebury, Phys. Lett. A 62 (1977) 337

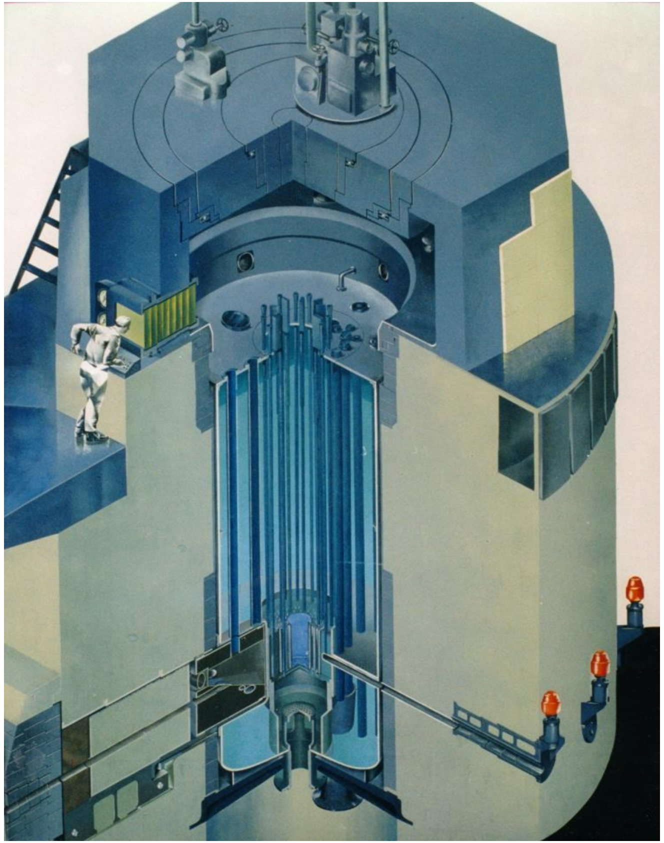


The history of the development of the idea in the talk of Oliver Zimmer

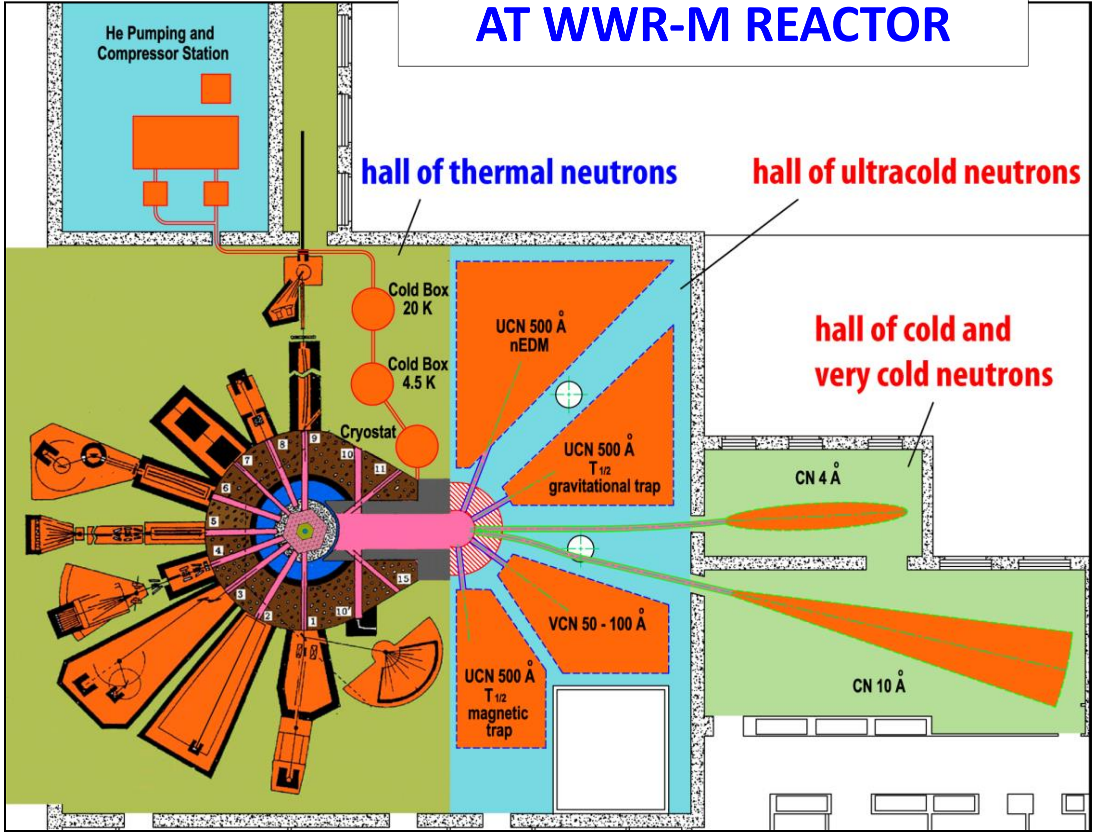
Development of UCN source projects on superfluid He-II at PNPI (Gatchina, Russia)

We decided to build our own UCN source at the WWR-M reactor

UCN SOURCE
AT WWR-M REACTOR



The operational life of the WWR-M reactor tank is another 25 years



Layout of cryogenic and experimental equipment in the main hall of the WWR-M reactor

Results of MCNP calculations of neutron fluxes and heat gains in the thermal column of the WWR-M reactor at a power of 16 MW

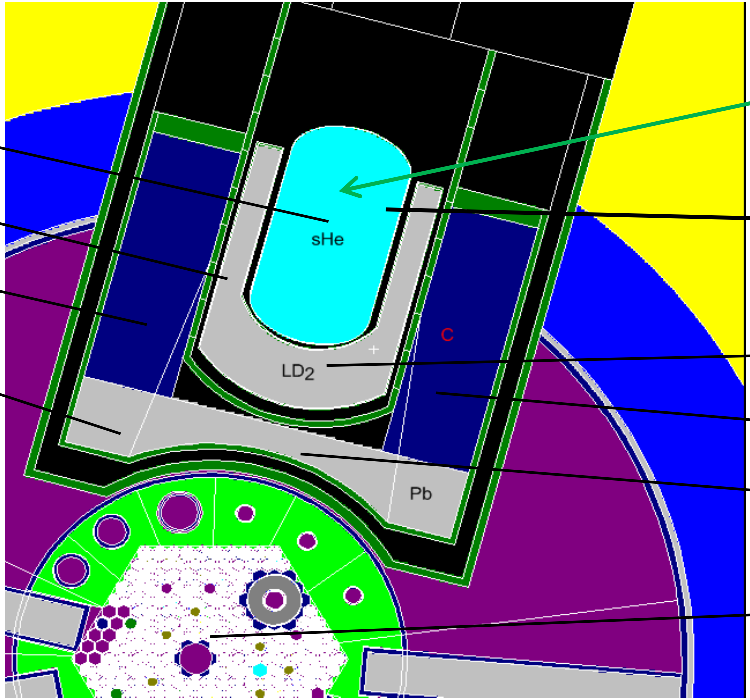
The main question is whether it is possible to remove 20 W of thermal power with superfluid helium

He T=1.2 K

LD_2 T=20 K

C T=300 K

Pb T=300 K



$\Phi=4.5\cdot10^{12}$ n/(cm^{2}s)

$\Phi(\lambda=9$ A$)=3\cdot10^{10}$ n/(cm^{2}sA)

$Q_{He}=6$ W

Al, $Q_{Al}=13$ W

19 W

LD_2, $Q_{LD2+Al}=100$ W

C, $Q_C=700$ W

Pb, $Q_{Pb}=15$ кW

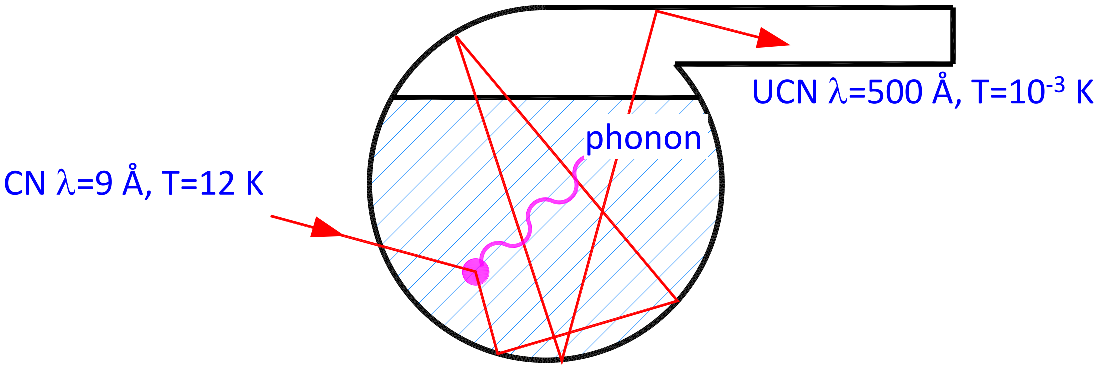
$\Phi=10^{14}$ n/(cm^{2}s)

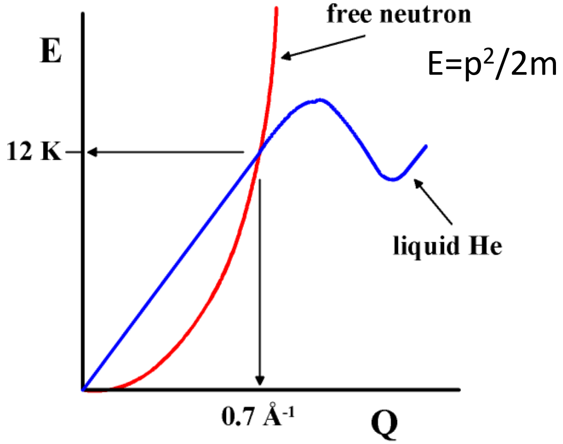
Q=15 MW

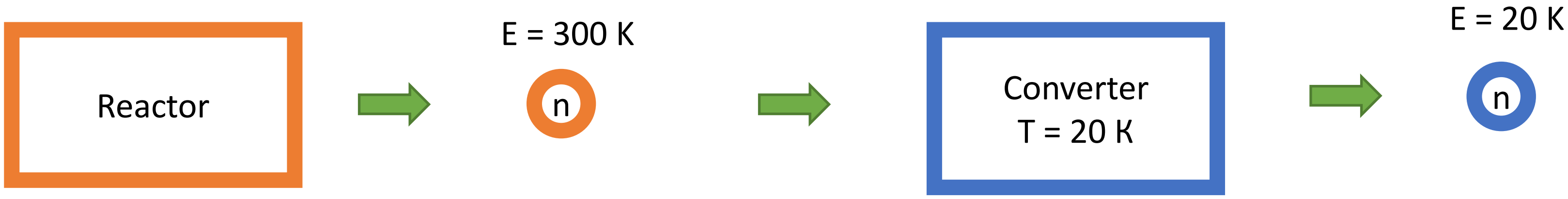
NIMA 611 (2009) 276
Physics of the Solid State 52 (2010) 969
Crystallography Reports 56 (2011) 1230
Technical Physics 60 (2015) 1238
Technical Physics 62 (2017) 633

The main idea is to produce and accumulate UCN in the source itself

1. UCNs are generated in helium from cold neutrons of 9Å wavelength (12 K energy).
2. Cold neutron produces phonon, practically stops and becomes an ultracold one.
3. UCN can “lives” in superfluid helium for tens or hundreds of seconds until a phonon be captured.
4. Cold neutrons (9Å) penetrate through the wall of a trap, but ultracold neutrons (500Å) are reflected.







Reactor

E = 300 K

n

Converter
T = 20 K

E = 20 K

n

Cryogenic complex of the WWR-M reactor

Hall of the cryogenic equipment

Helium liquefier and refrigerator

Vacuum equipment

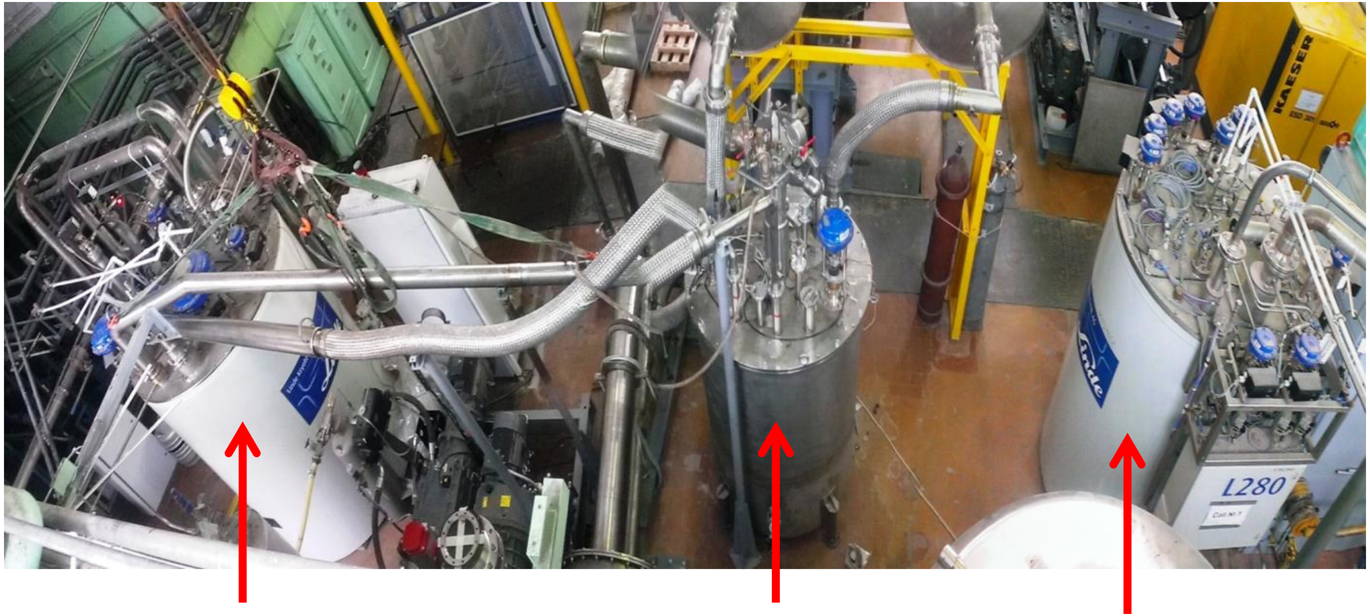
Cryostat

Compressor
high pressure

Helium
receivers

1. UCN source model is a superfluid helium container (35 liters) covered by a wire heater.
2. The wire heater simulates reactor heat load.
3. UCN source model is located inside cooper heat shield (T=15K)

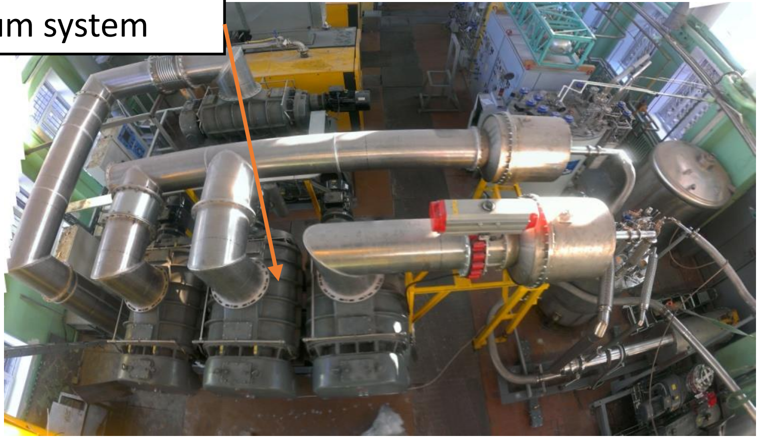
Full-scale UCNS model complex with superfluid helium has been launched



Refrigerator **Helium cryostat** **Liquefier**

Main question: whether it is possible to take away 20 W of heat from superfluid helium?
(Full-scale model of UCN source was tested)

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

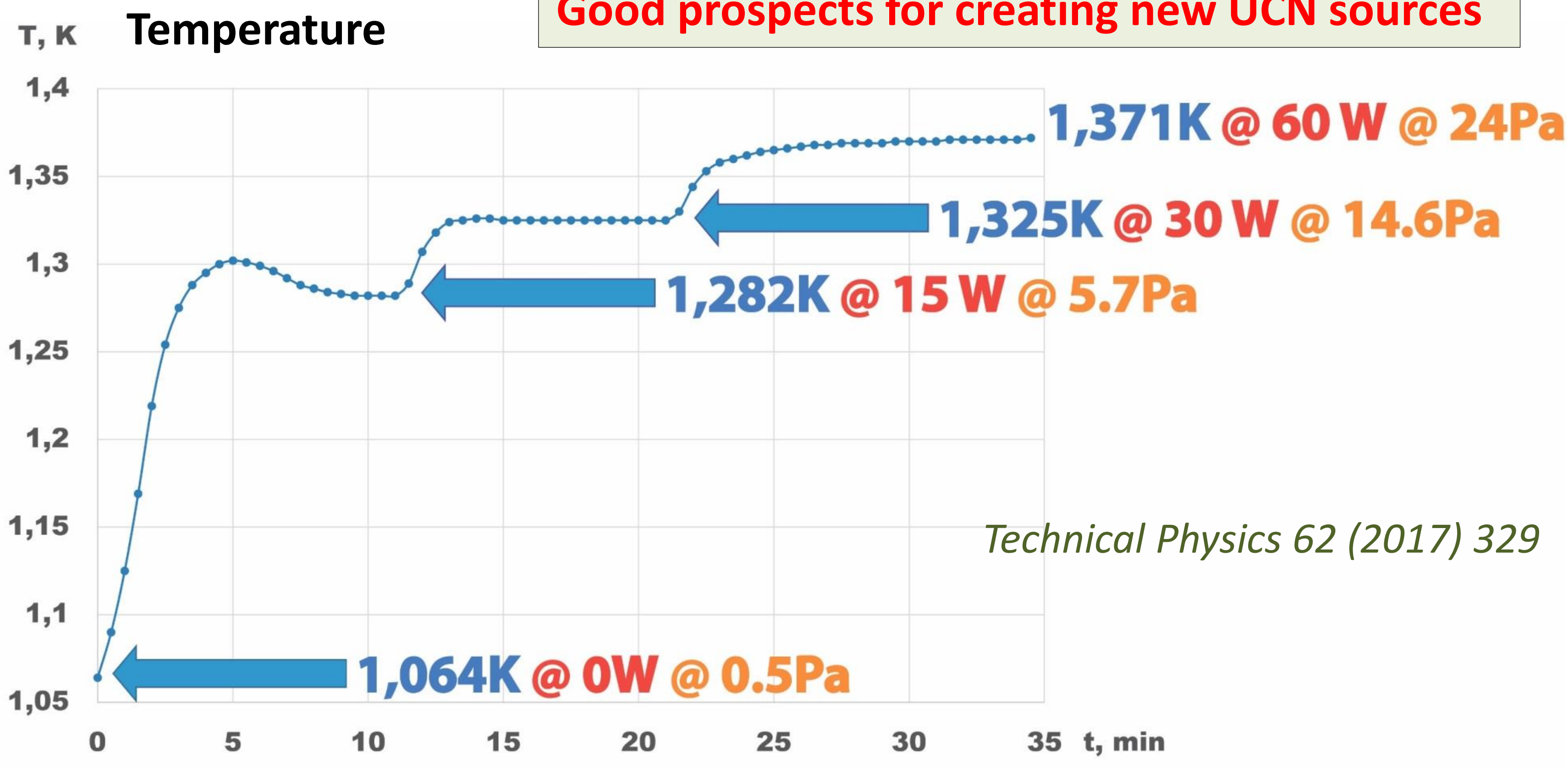


Temperature received superfluid helium 1.08 K in a cryostat bath

Temperature received superfluid helium 1.3K in a UCN source at a load of 15 W

Even 60W power can be removed !

Good prospects for creating new UCN sources



1,371K @ 60 W @ 24Pa

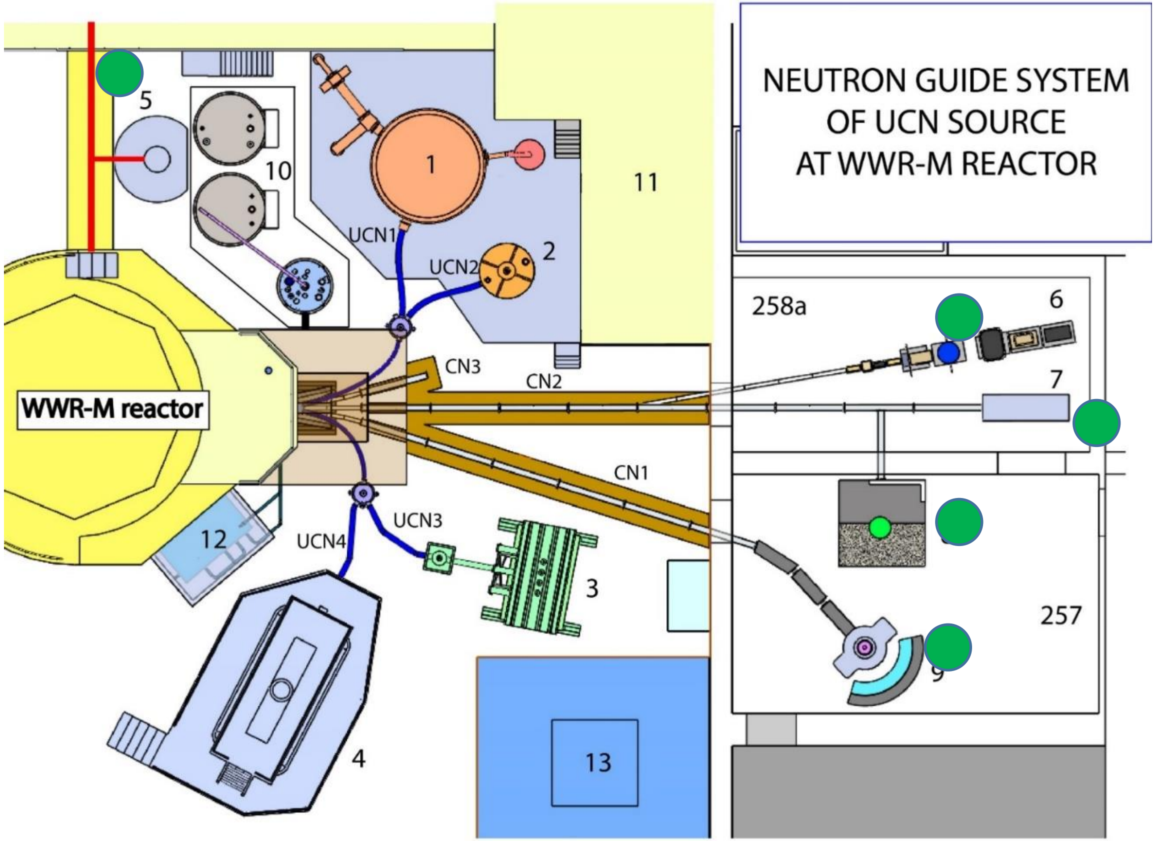
1,325K @ 30 W @ 14.6Pa

1,282K @ 15 W @ 5.7Pa

1,064K @ 0W @ 0.5Pa

Technical Physics 62 (2017) 329

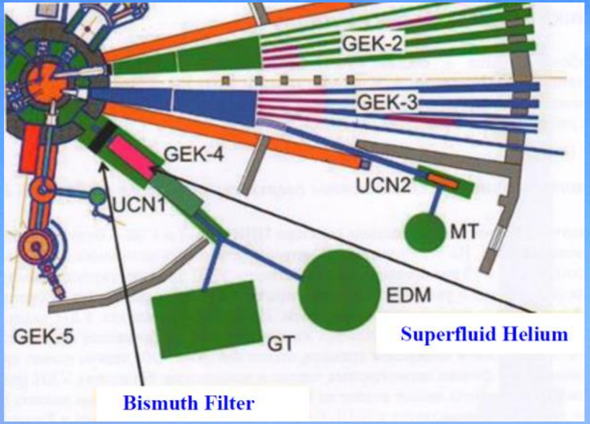
UCN source at the WWR-M reactor and scientific program



1 - EDM spectrometer
2 – UCN magnetic trap
3 - Experiment n-n'
4 – UCN gravitational trap
5 – Diffractometer
6 - Reflectometer
7 - Polarimeter
8 - Powder diffractometer
9 - Spin-echo spectrometer
10 – UCN source cryogenic equipment
11 - Technological platform for experimental equipment
12 – Cooling system for the lead shield of the UCN source
13 - Transport entrance to the main hall of the WWR-M reactor

ISSN 10637842, Technical Physics, 2015, Vol. 60, No. 8, pp. 1238–1242.

The PIK reactor must be equipped with UCN source



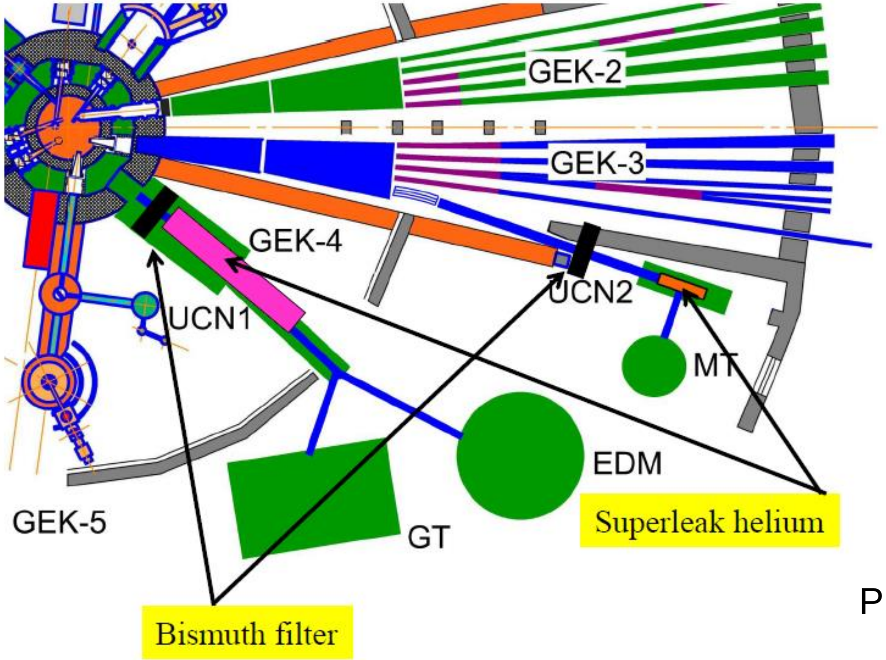
- Thermal power100 mW
- Flux density of thermal neutrons (maximum)$5*10^{15}$cm^{-2}*c^{-1}
- Flux density of thermal neutrons in the reflector $1,5*10^{15}$cm^{-2}*c^{-1}

ISSN 1063-7788, Physics of Atomic Nuclei, 2016, Vol. 79, No. 3, pp. 293–303.

ISSN 1063-7745, Crystallography Reports, 2016, Vol. 61, No. 1, pp. 144–148.

First Version

UCN source at PIK reactor



- **UCN1** – UCN source at GEK-4 channel,
- **UCN2** – UCN source at GEK-3 channel,
- **EDM** – neutron EDM spectrometer,
- **GT** – neutron lifetime setup with gravitational trap,
- **MT** – neutron lifetime setup with magnetic trap.

Technical Physics Letters 40 (2014) 10
ISSN 1063-7850, Technical Physics Letters, 2015, Vol. 41, No. 10, pp. 1016–1018.

Physics - Uspekhi 58 (11) 1074 - 1094 (2015)

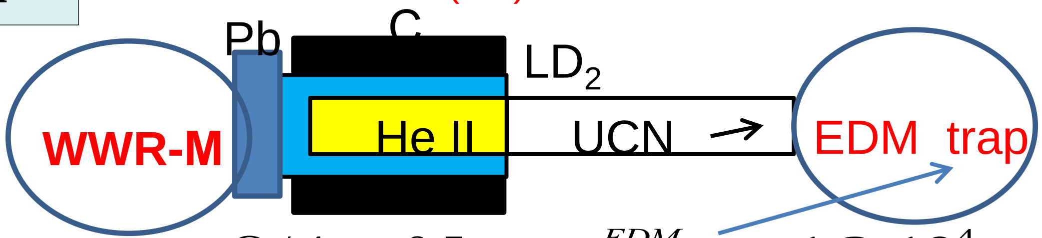
Schemes of UCN sources to compare the projects for WWR-M reactor and PIK reactor

Zero approximation

WWR-M
He II inside
thermal column

$\Phi_{th} = 3.2\cdot10^{12}$ $n\cdot cm^{-2}s^{-1}$

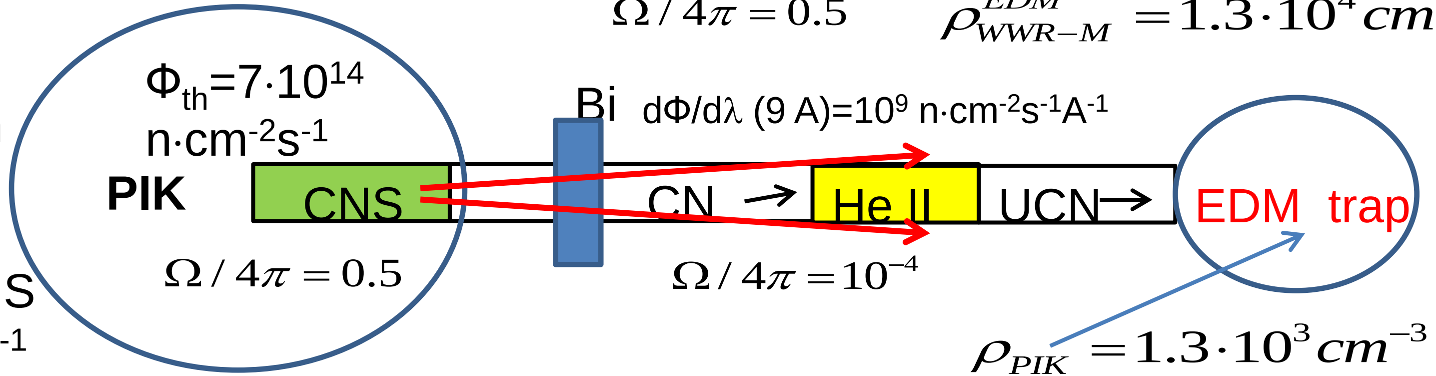
$d\Phi/d\lambda\ (9\ A) = 3.2\cdot10^{10}\ n\cdot cm^{-2}s^{-1}A^{-1}$



$$\Omega / 4\pi = 0.5$$

$$\rho^{EDM}_{WWR-M} = 1.3\cdot10^{4}\,cm^{-3}$$

PIK
GЭК 4-4
He II on the beam



$\Phi_{th} = 7\cdot10^{14}$ $n\cdot cm^{-2}s^{-1}$

$d\Phi/d\lambda\ (9\ A) = 10^{9}\ n\cdot cm^{-2}s^{-1}A^{-1}$

$$\Omega / 4\pi = 0.5$$

$$\Omega / 4\pi = 10^{-4}$$

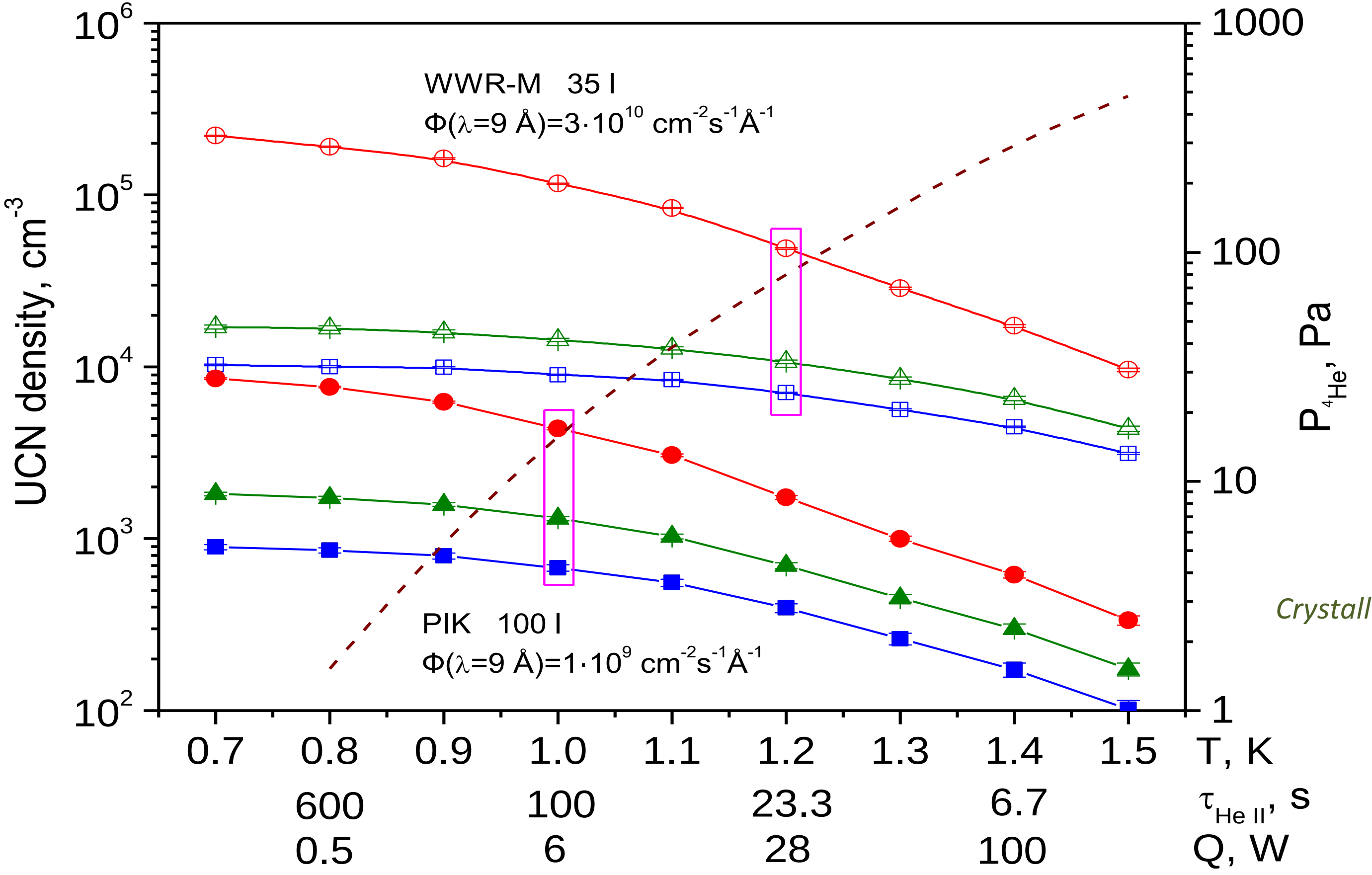
$$\rho_{PIK} = 1.3\cdot10^{3}\,cm^{-3}$$

Thermal flux in CNS
$\Phi_{th} = 7\cdot10^{14}\ ncm^{-2}s^{-1}$

$$\Phi_{WWR}\cdot\Omega_{WWR} / \Phi_{PIK}\cdot\Omega_{PIK} = 50$$

$$\rho_{WWR} / \rho_{PIK} = 10$$

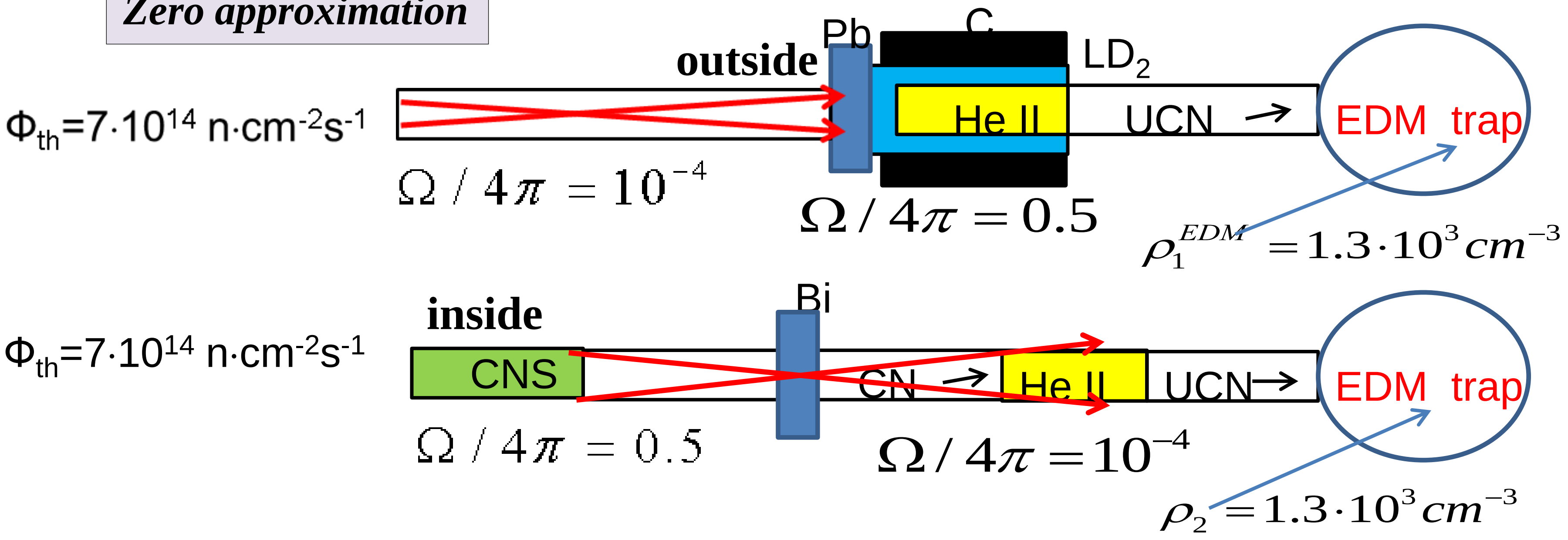
Comparison two scheme of UCN sources (WWR-M and PIK)



Crystallography Reports 61 (2016) 144

Compare of two schemes of UCN sources for PIK reactor – CNS inside or outside

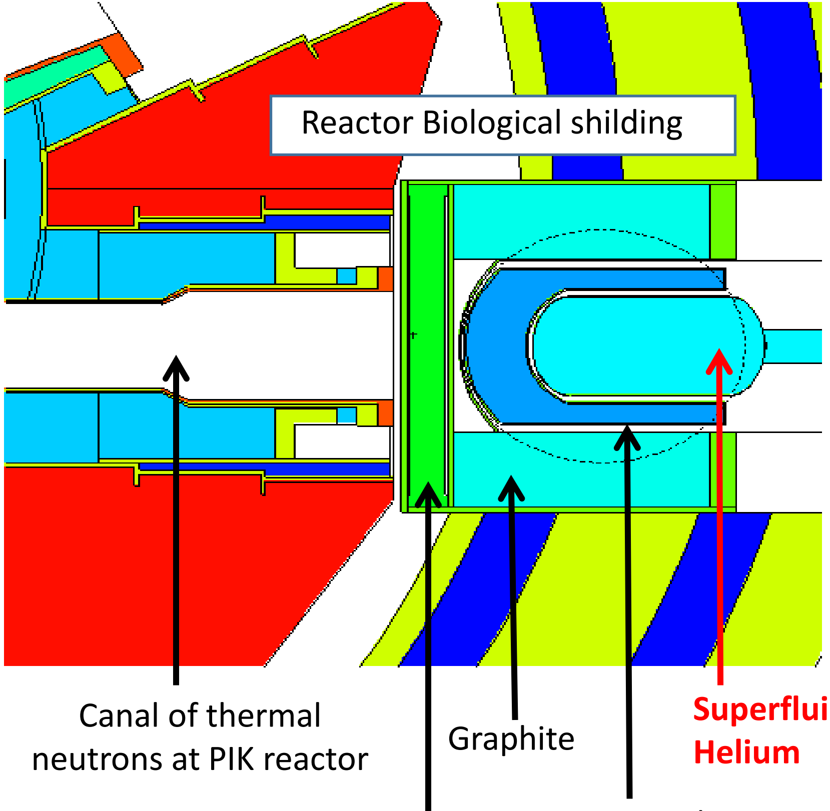
Zero approximation



$$\Phi_{CNS_{in}}\cdot\Omega_{beam}/\Phi_{Th}\cdot\Omega_{CNS_{out}}=1$$

$$\rho_1/\rho_2=1$$

Scheme of UCN source for PIK reactor and calculations of neutron flux



Reactor Biological shilding

Canal of thermal neutrons at PIK reactor

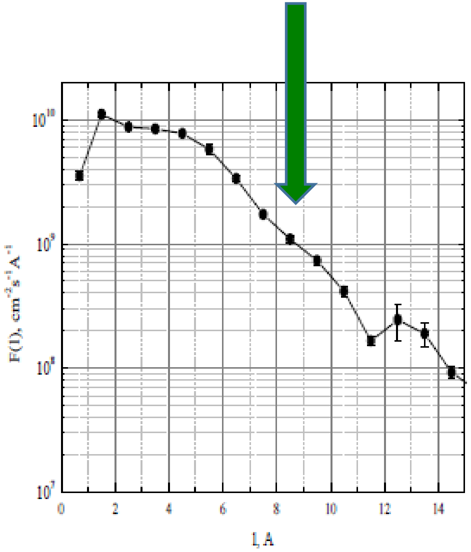
Lead shielding

Graphite

Liquid deuterium

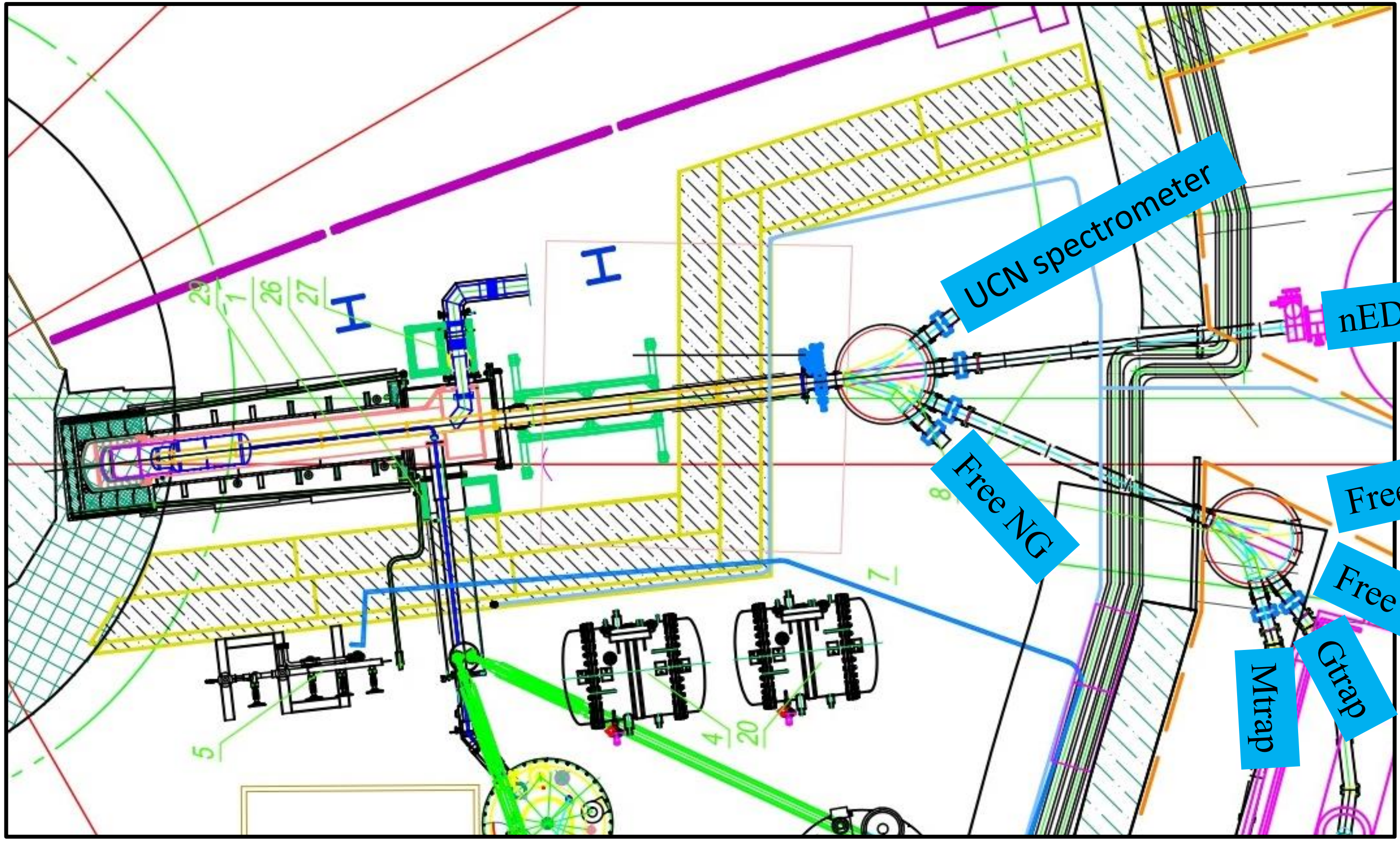
Superfluid Helium

Flux density at 9 Å is $10^9 cm^{-1}s^{-1}A^{-1}$

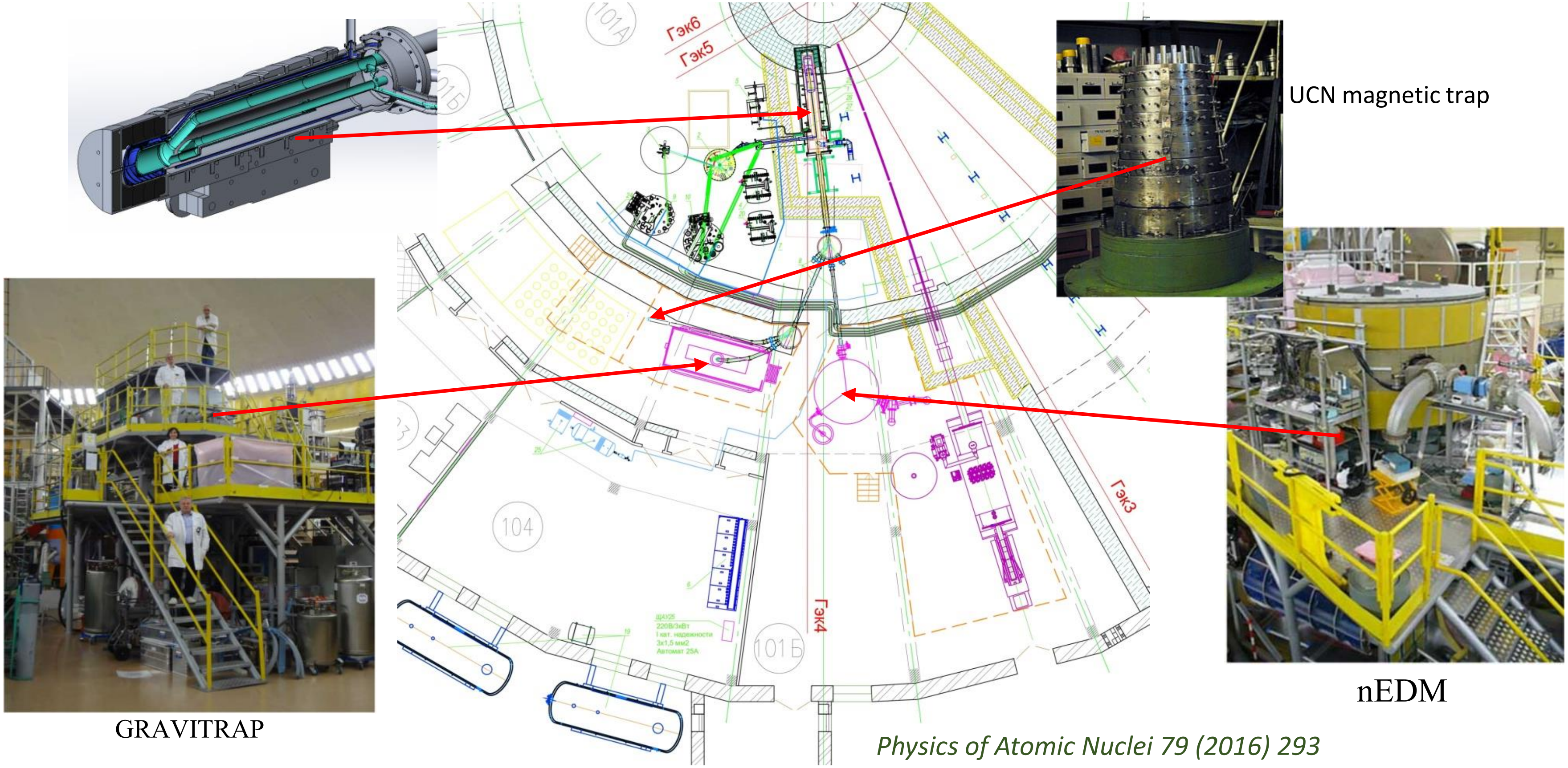


Flux density of neutrons depending on wavelength in helium chamber

SCHEEME OF ULTRACOLD NEUTRON BEAMS



SCIENTIFIC RESEARCH PROGRAM



UCN magnetic trap

GRAVITRAP

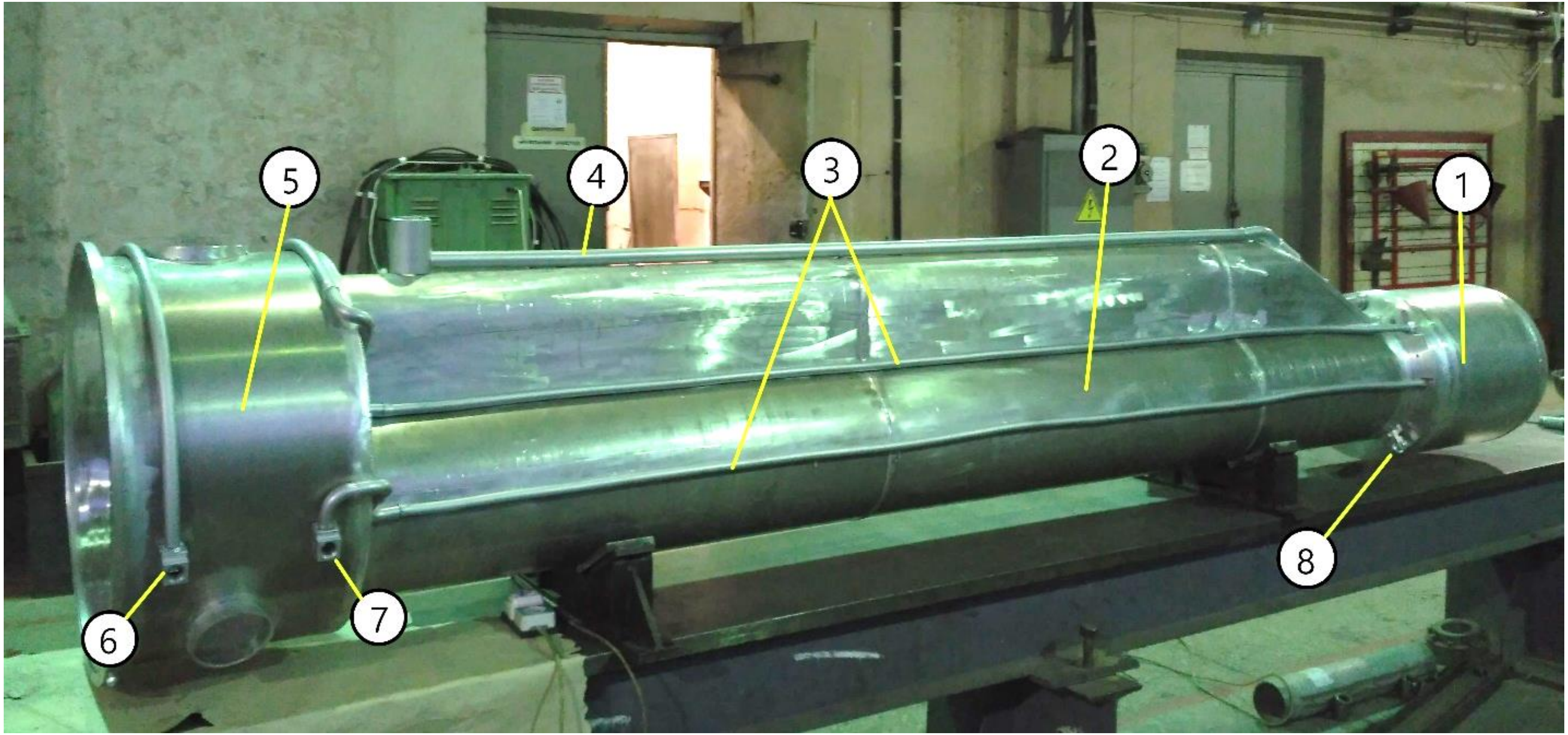
nEDM

Physics of Atomic Nuclei 79 (2016) 293
Technical Physics 92 (2022) 327

Assembly/testing of the source

Checking source geometry after welding

Assembling of D2 module

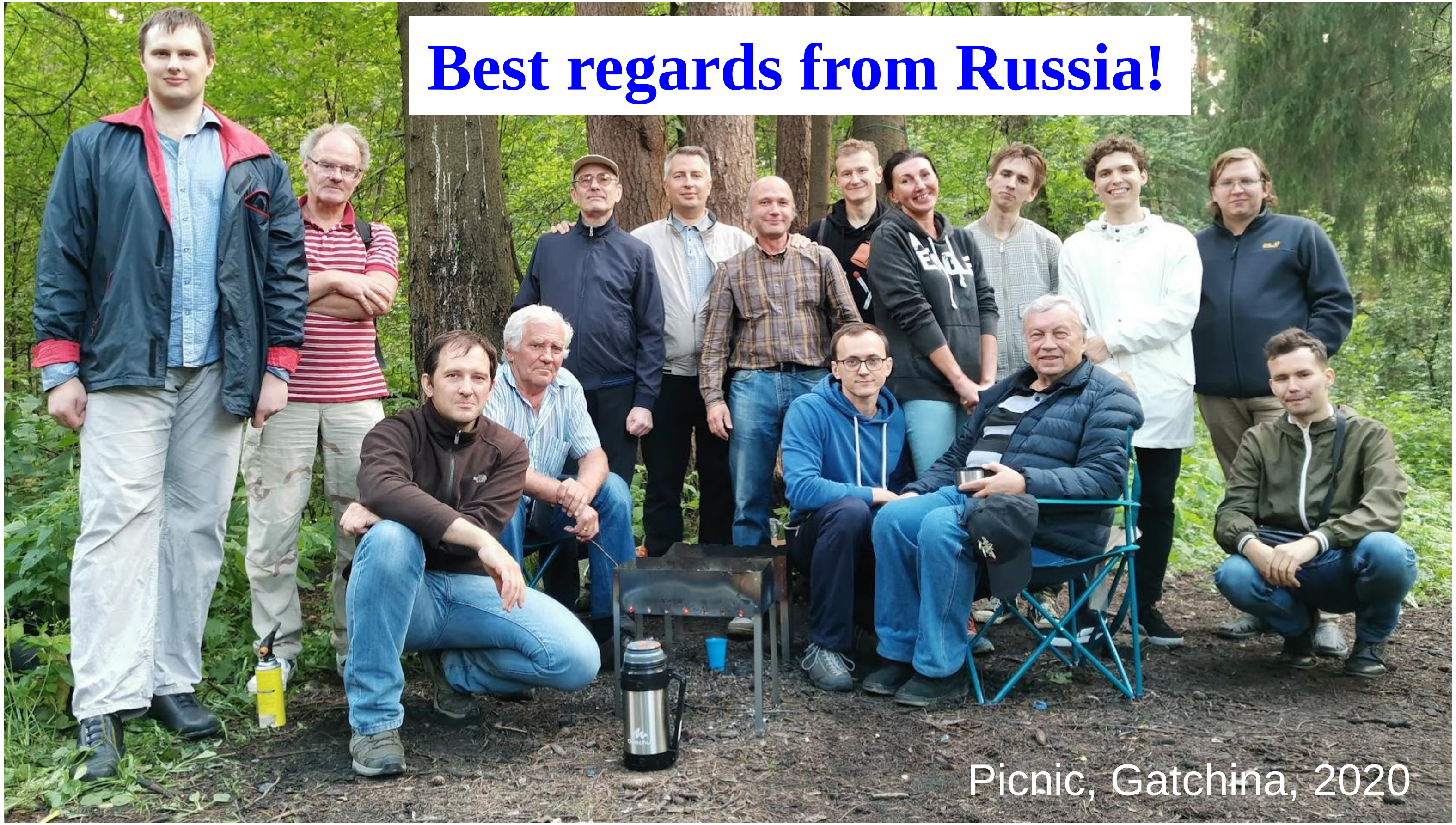


1- D2 vessel; 2- 20K heat shield; 3- Helium supply pipes; 4- D2 supply pipe; 5- 20K heat shield extension; 6,7- helium supply flanges; 8- roller seat

Supply of R-20 and R-30 receivers

Vessels for isotopically pure helium

Best regards from Russia!



Picnic, Gatchina, 2020

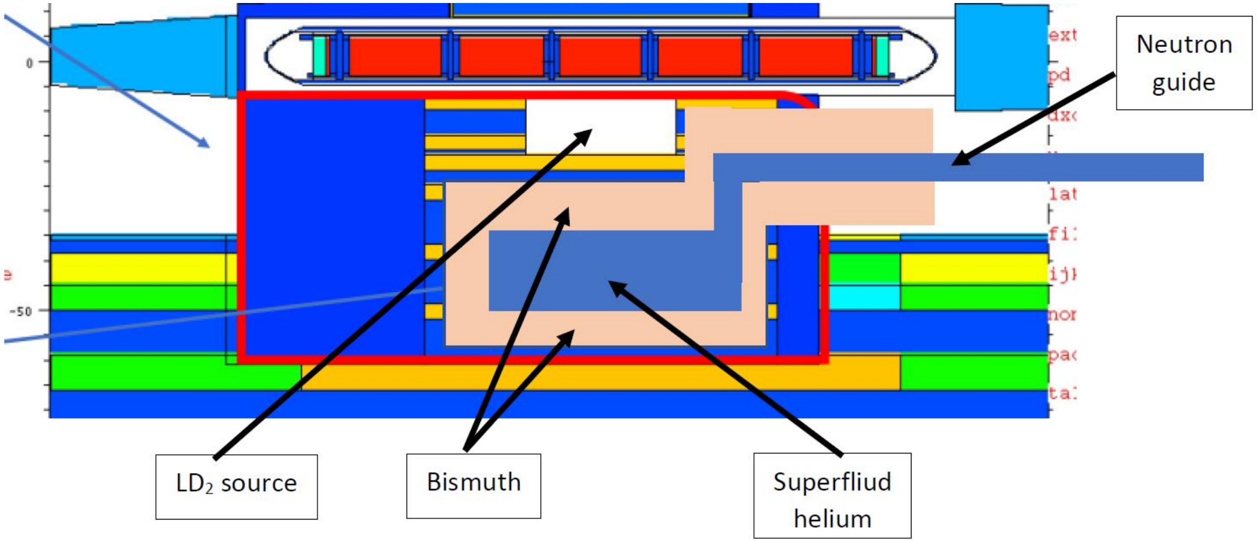
Our proposals for ESS UCN source

Sent 13 November 2020

VERSION 1 (inside)

It seems that heat load on superfluid helium will be at level of several tens of Wats. We will need to put proper (very powerful) cryogenic and pumping facilities just beside the superfluid helium. Most likely due to technical features it can not be realized. Anyway, it is interesting to know at what order of magnitude specific heat release will be in such scheme.

We think that in case it will be realized it will be the most powerful option.



Neutron guide

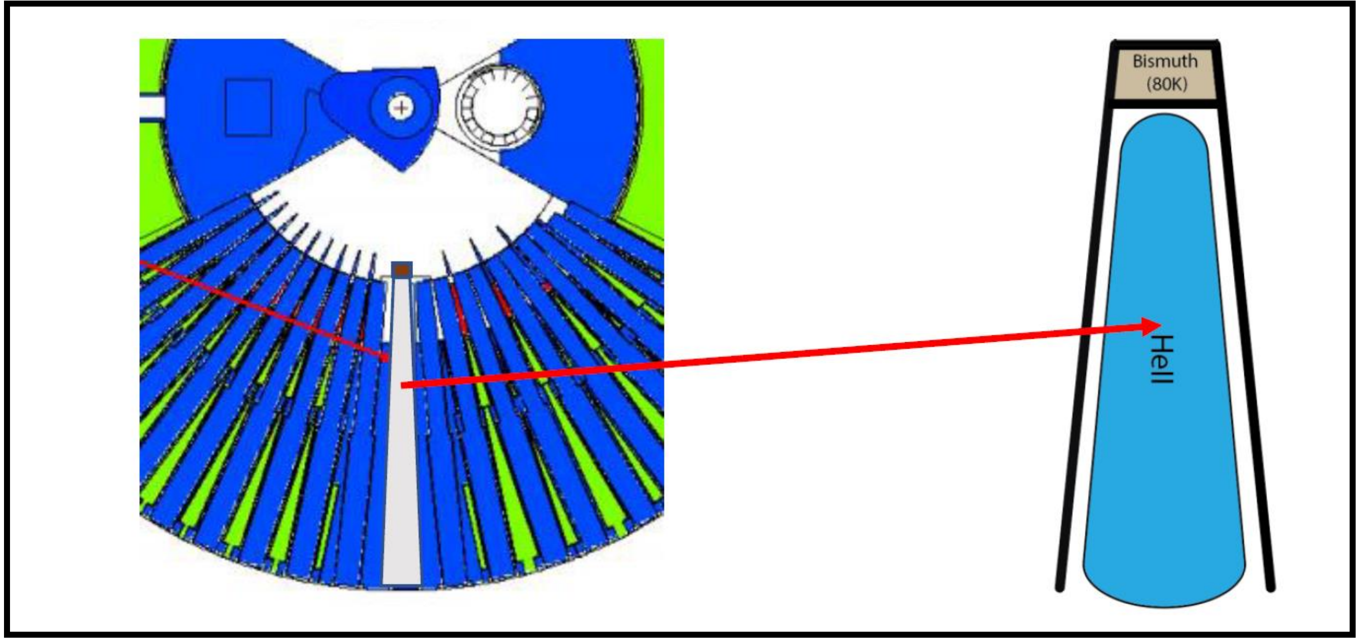
LD_2 source

Bismuth

Superfliud helium

VERSION 2 (in channel without LD2)

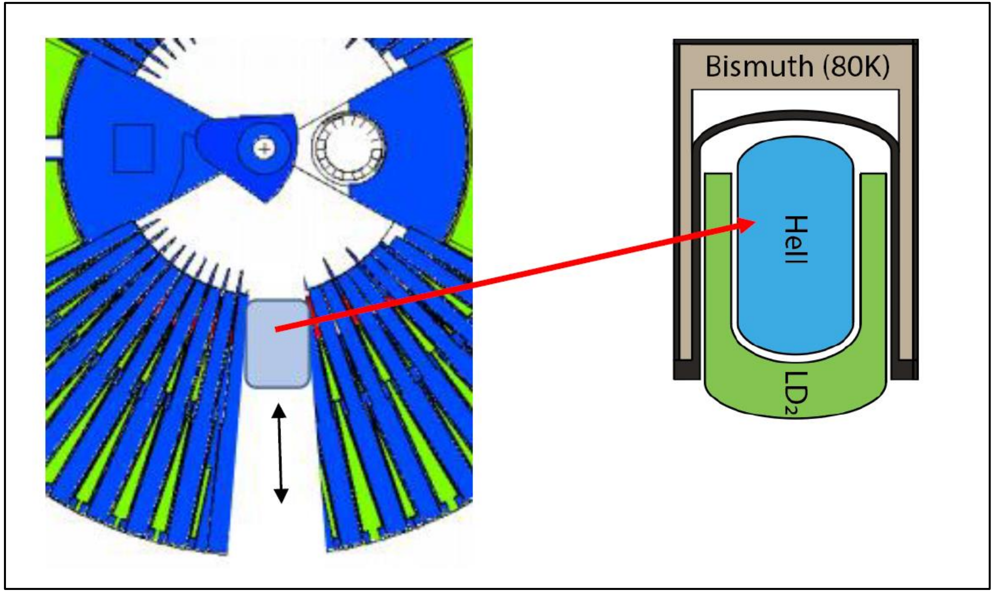
Width of insert at the tip is given as 160 mm. Most likely on the other side width will be much smaller. We need to install there vacuum vessel (min (15+15)mm thickness), helium vessel (min (2+2)mm thickness) and if necessary (upon confirmation during optimization) graphite/LD_2. Thus the maximum thickness of superfluid helium will not exceed 100 mm. Depending on heat incomes its length might be 2-3 meters. Inner part of channel in which UCN source in planted might be coated with cold neutron reflector.



VERSION 3 (in channel with LD2)

Version 3 is the most suitable for us. It looks like improved option 4 inside the channel. It might be the best solution with respect to heat release and neutron fluxes. It is worth thinking about removing not 3 but 5 channels to be sure that we will have enough space to install all the equipment.

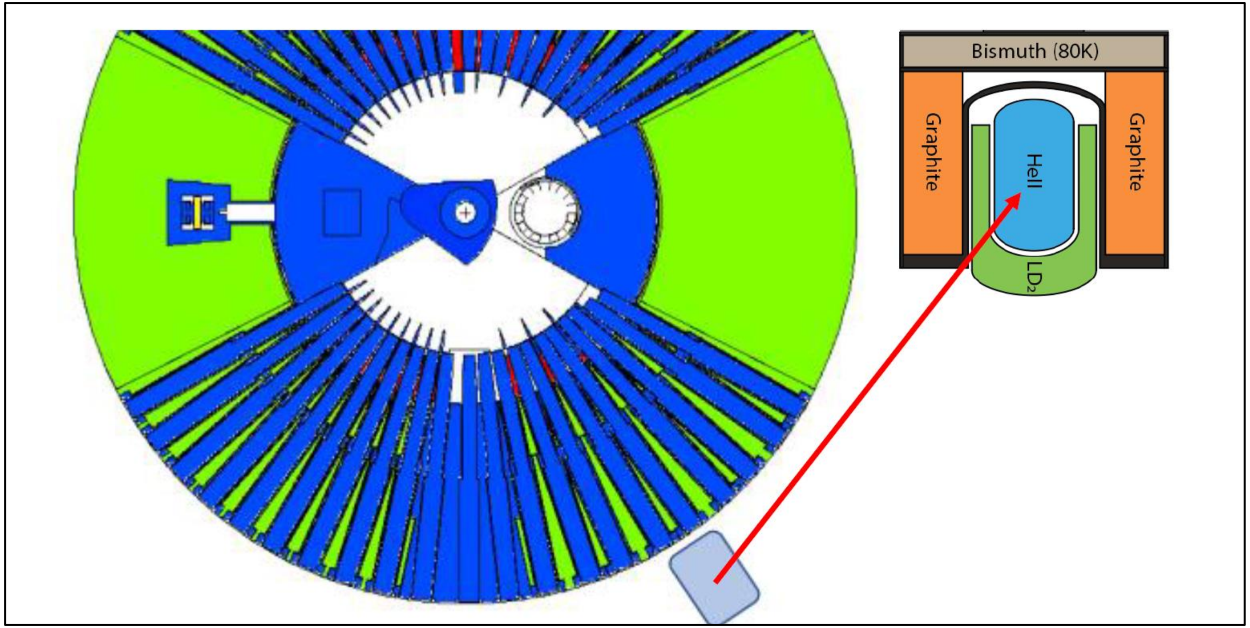
Someone has to make Monte Carlo calculations of heat release in superfluid helium. After that we can discuss the heat release scheme and so on.



VERSION 4 (outside)

This is classical PIK-2 scheme. It can be realized in case other opportunities will fail. Moreover, it can be realized ever after ESS will start.

Unfortunately, more likely this scheme will give the weakest UCN source proposed above.



Good luck!