Project of Big Gravitational Trap for neutron lifetime measurement ("Gravitrap II")

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"Ultra Cold & Cold Neutrons
Physics & Sources"
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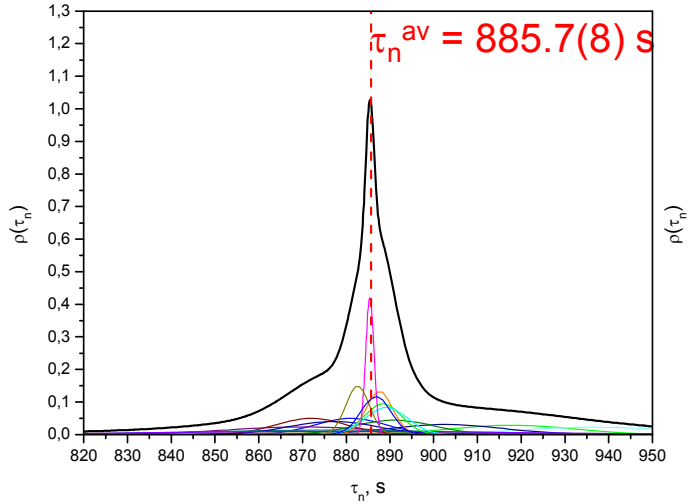
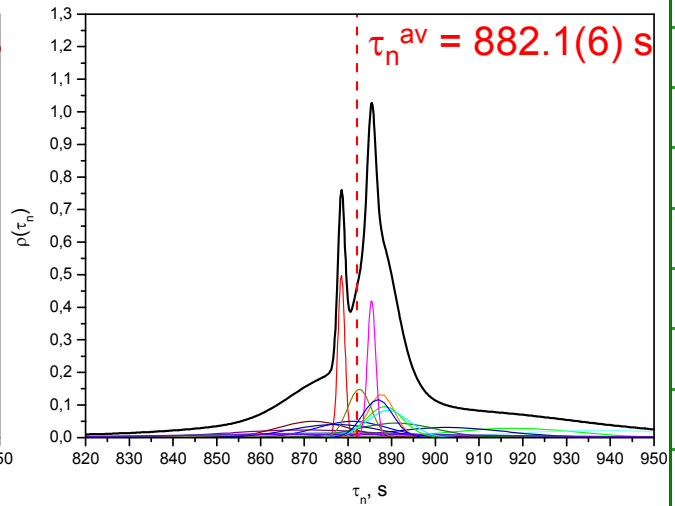
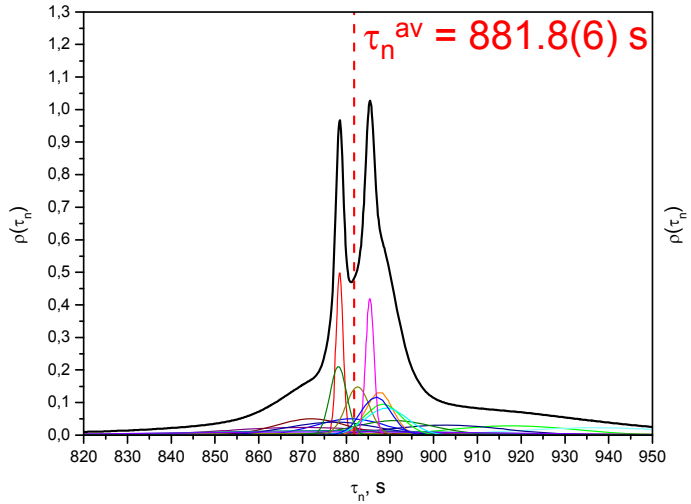
Motivation for preparation of new experiment



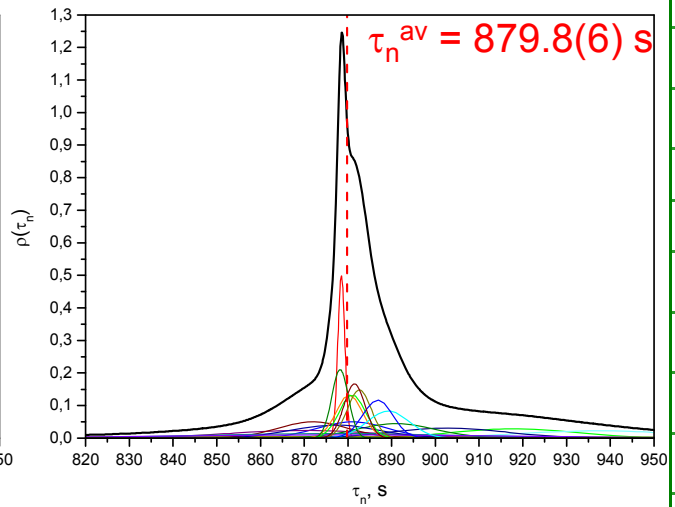
2003
before Gravitrap measurement



2004
after Gravitrap measurement

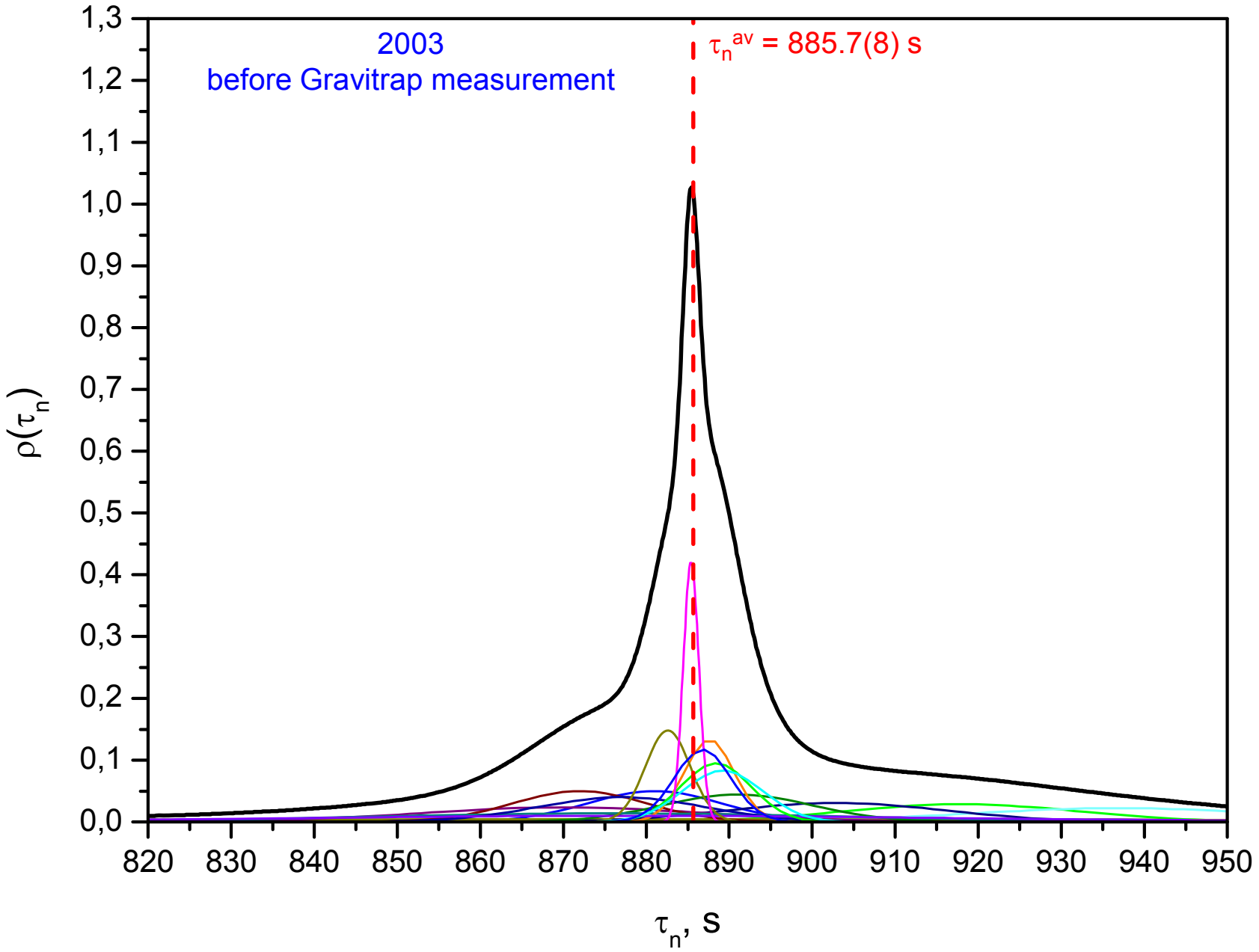


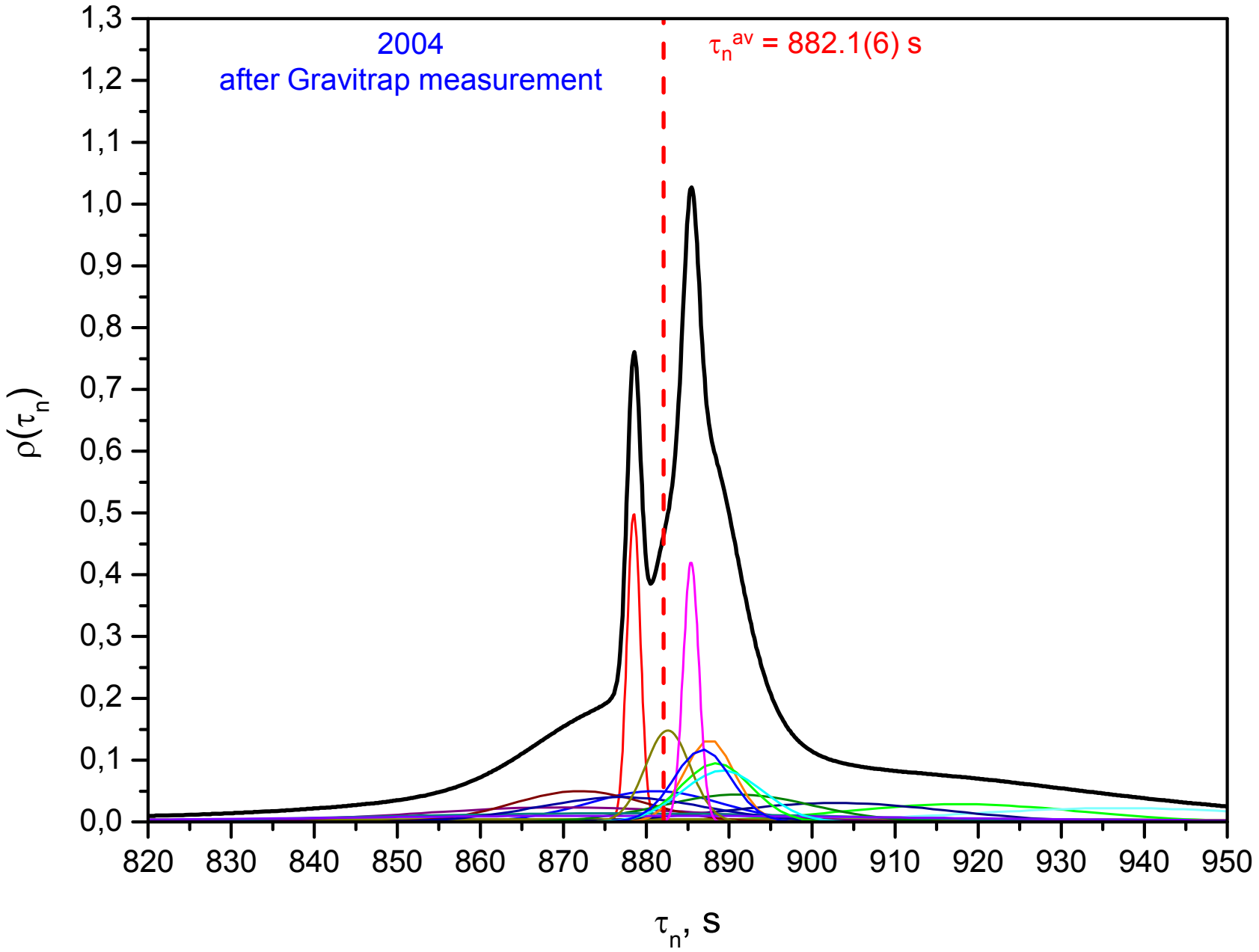
2007
after magnetic trap measurement



2009
new analysis

Lifetime τ[s]	Ref./Year
881.5 ± 2.4	V. Morozov et al. 2009
878.2 ± 1.9	V. Ezhov et al. 2007
878.5 ± 0.8	A. Serebrov et al. 2004
886.8 ± 3.42	M.S. Dewey et al. 2003
885.4 ± 0.95	S. Arzumanov et al. 2000
889.2 ± 4.8	J. Byrne et al. 1995
882.6 ± 2.7	W. Mampe et al. 1993
888.4 ± 3.1 ± 1.1	V. Nesvizhevski et al. 1992
878 ± 27 ± 14	R. Kosakowski 1989
887.6 ± 3.0	W. Mampe et al. 1989
877 ± 10	W. Paul et al. 1989
876 ± 10 ± 19	J. Last et al. 1988
891 ± 9	P. Spivac et al. 1988
872 ± 8	A. Serebrov et al. 1987
870 ± 17	M. Arnold et al. 1987
903 ± 13	Y.Y. Kosvintsev et al. 1986
875 ± 95	Y.Y. Kosvintsev et al. 1980
937 ± 18	J. Byrne et al. 1980
881 ± 8	L. Bondarenko et al. 1978
918 ± 14	C.J. Christensen et al. 1972


2003
before Gravitrap measurement
τ_n^{av} = 885.7(8) s
$\rho(\tau_n)$
τ_n, s
1,3
1,2
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
820
830
840
850
860
870
880
890
900
910
920
930
940
950


2004
after Gravitrap measurement
τ_n^{av} = 882.1(6) s
$\rho(\tau_n)$
τ_n, s
1,3
1,2
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
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820
830
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850
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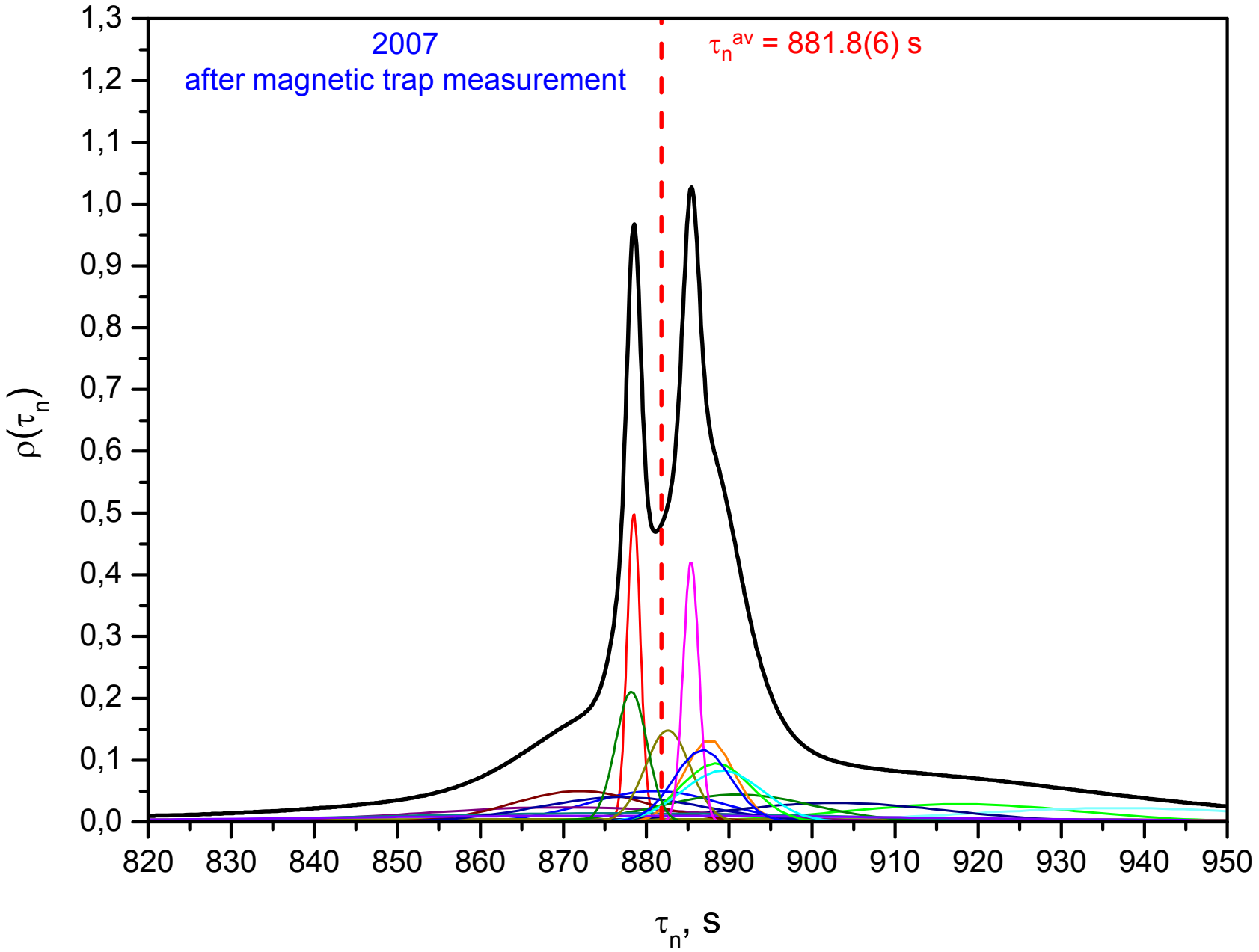
2007
after magnetic trap measurement
τ_n^{av} = 881.8(6) s
$\rho(\tau_n)$
τ_n, s
1,3
1,2
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
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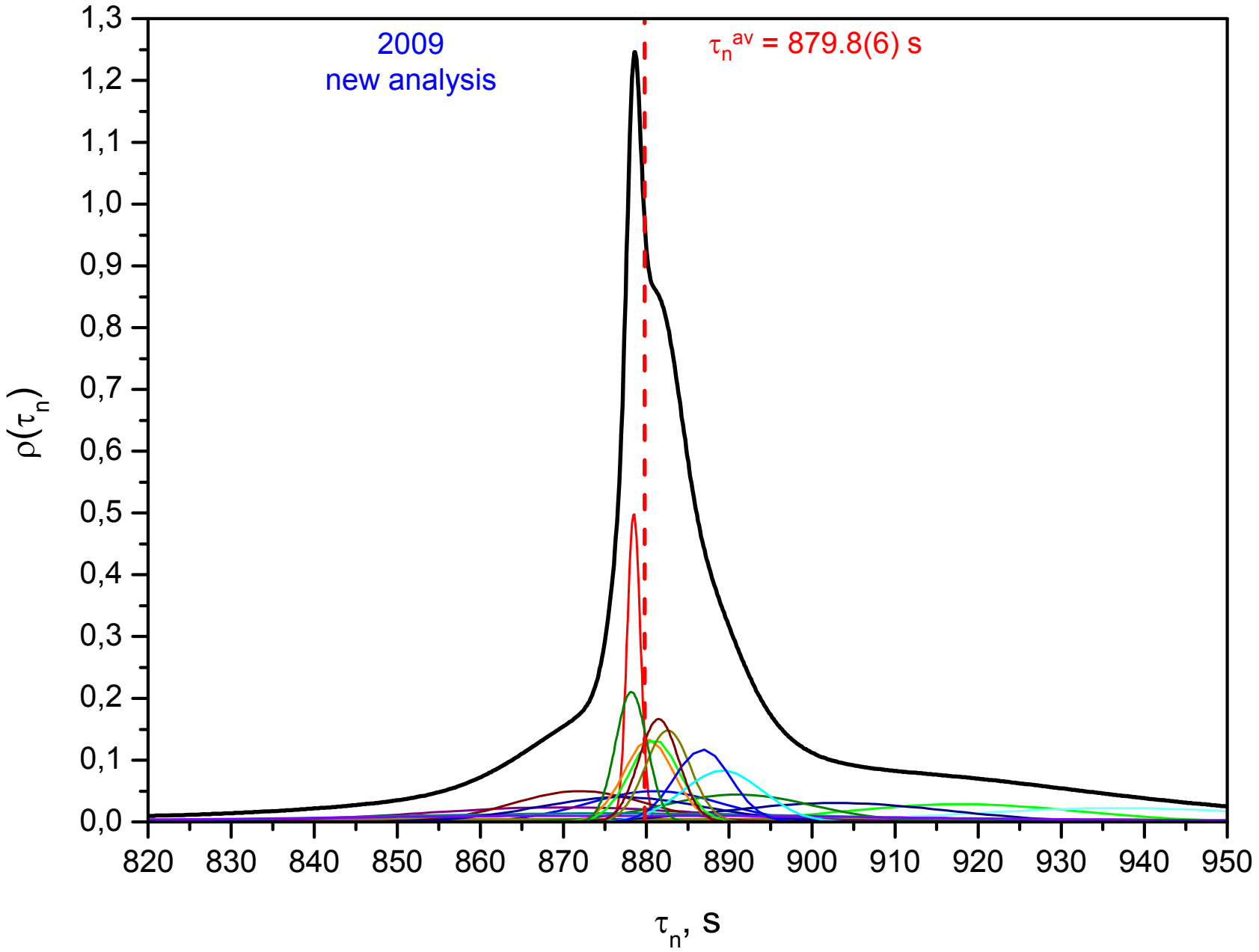
2009
new analysis
τ_n^{av} = 879.8(6) s
$\rho(\tau_n)$
τ_n, s
1,3
1,2
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
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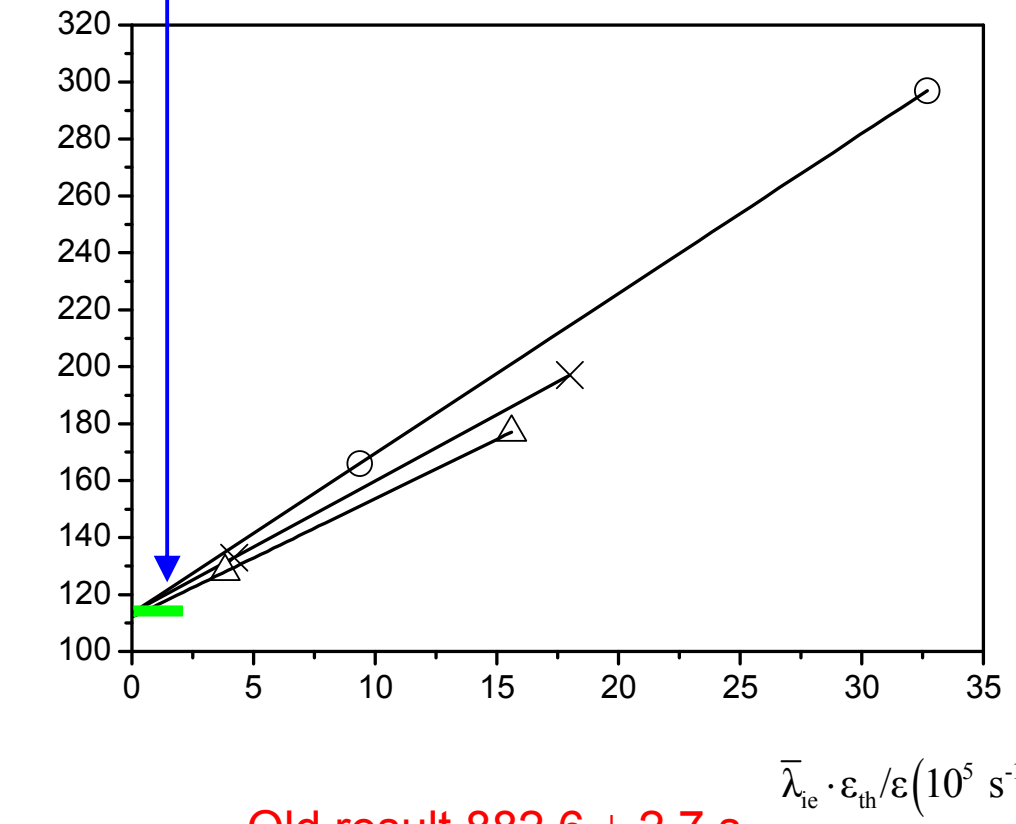
Comparison of UCN loss factors for PNPI-ILL (A. Serebrov et al.) and KIAE-ILL (V. Morozov et al.) experiments

In PNPI-ILL experiment the difference between storage time and neutron lifetime is about 5 s, for KIAE-ILL experiment it is about 100 s.

This green box is area of PNPI data (UCN loss factor is less by the factor of 20 times).



Old result 882.6 ± 2.7 s

New result 881.5 ± 2.4 s

Last result

$\tau_n = 885.4 \pm 0.9_{stat} \pm 0.4_{syst}$

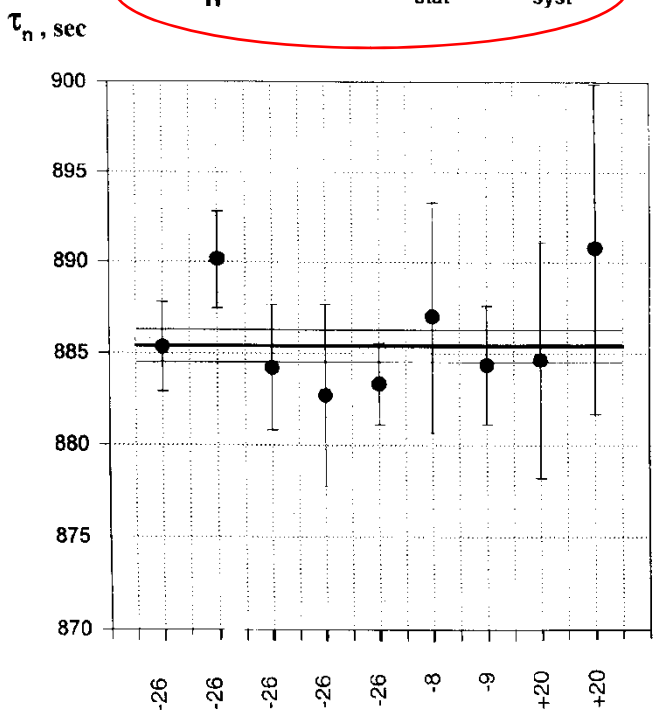


Fig. 3. Experimental values for the neutron life time from the different runs. The code for the experimental groups corresponds to the bottle temperatures −26°C, −9°C, −8°C and +20°C, respectively. The total measuring time summed up to 100 days.

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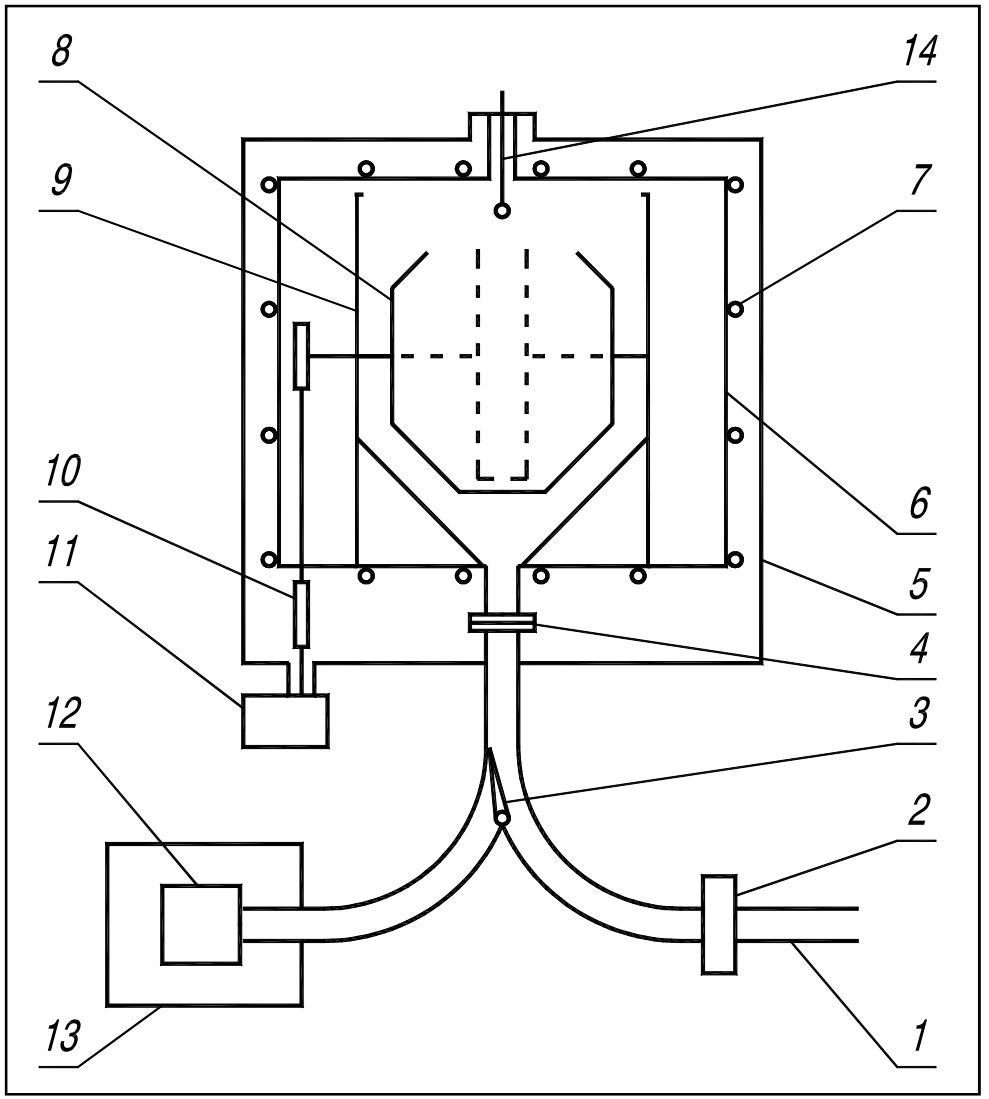
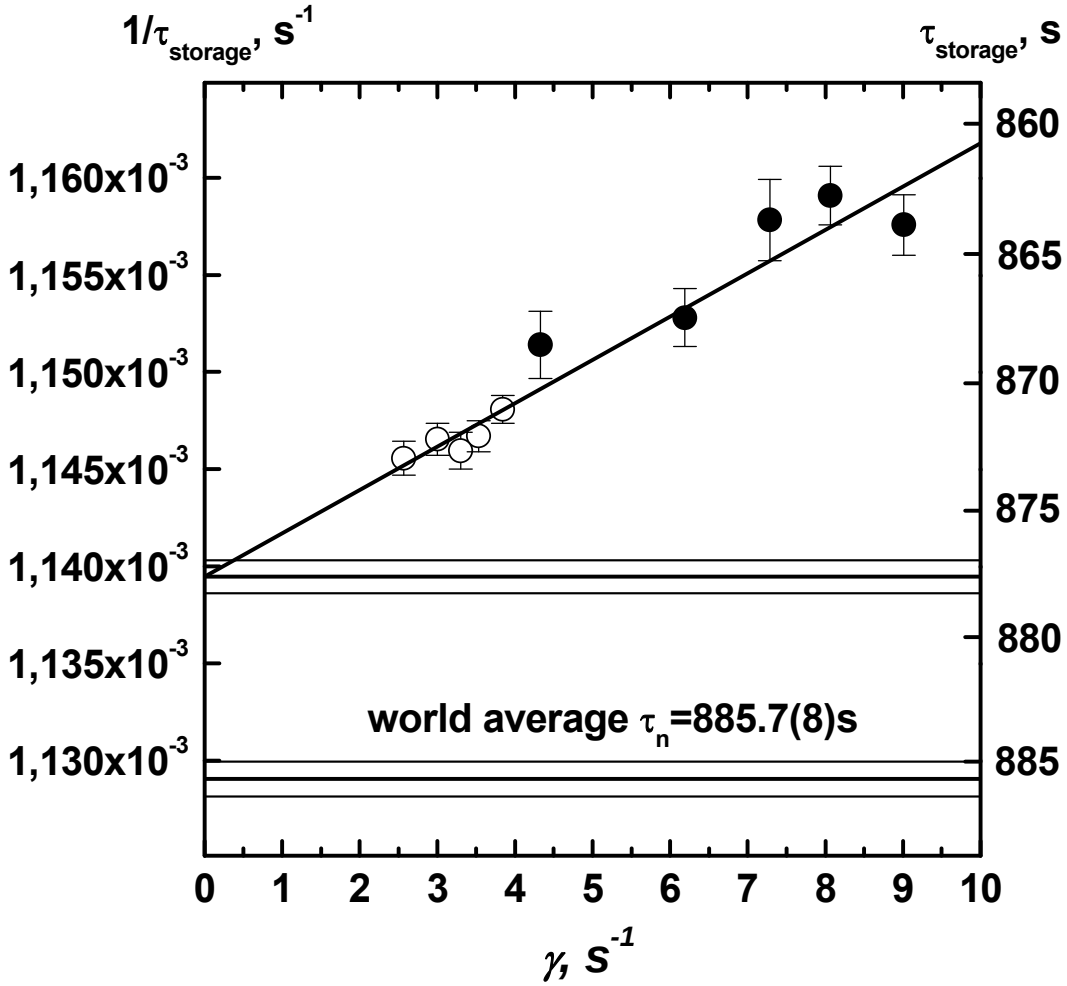
Scheme of “Gravitrap” - the gravitational UCN storage system (old experiment)



Extrapolation to n-lifetime (results of old experiment (2004))



The neutron lifetime obtained,
$878.5 \pm 0.7_{stat} \pm 0.3_{sys}$ s *
is the most accurate experimental measurement to date.

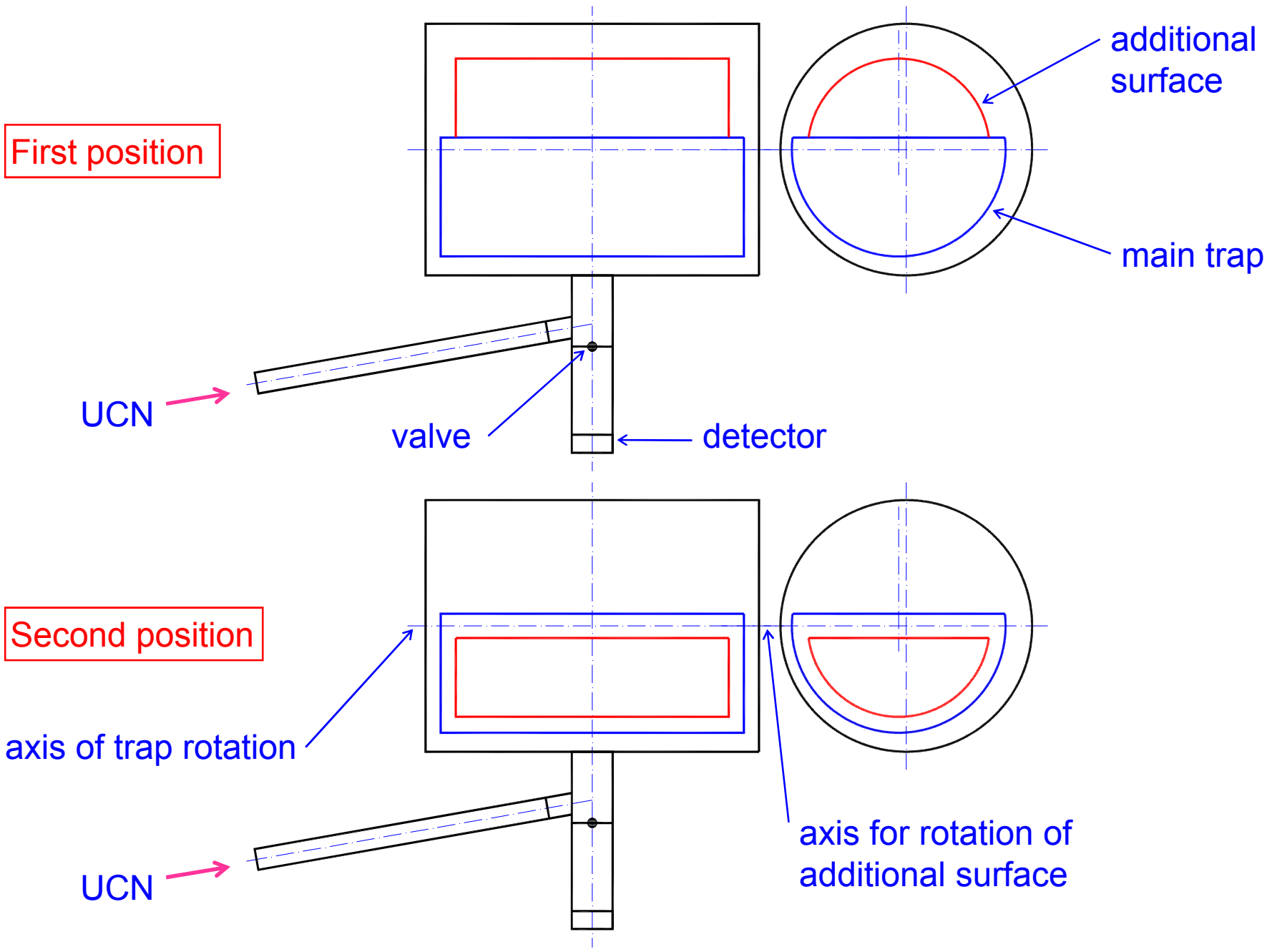
*A. Serebrov et al., Phys. Lett. B605, 72 (2005)
A. Serebrov et al., Physical Review C 78, 035505 (2008)

List of systematic corrections and uncertainties of old experiment

Effect	Magnitude, s	Uncertainty, s
n-lifetime (size extrapolation)	878.07	0.73
Method of calculating γ	0	0.236
Influence of shape of function μ(E)	0	0.144
UCN spectrum uncertainty	0	0.104
Uncertainty of trap dimensions (1 mm)	0	0.058
Residual gas effect	0.4	0.024
Uncertainty in PFPE critical energy (20)	0	0.004
Total systematic correction	0.4	0.3
Final n-lifetime	878.5	$\pm 0.7_{stat} \pm 0.3_{sys}$

The main task is improvement of statistical accuracy

New scheme of Big Gravitational Trap (main ideas)

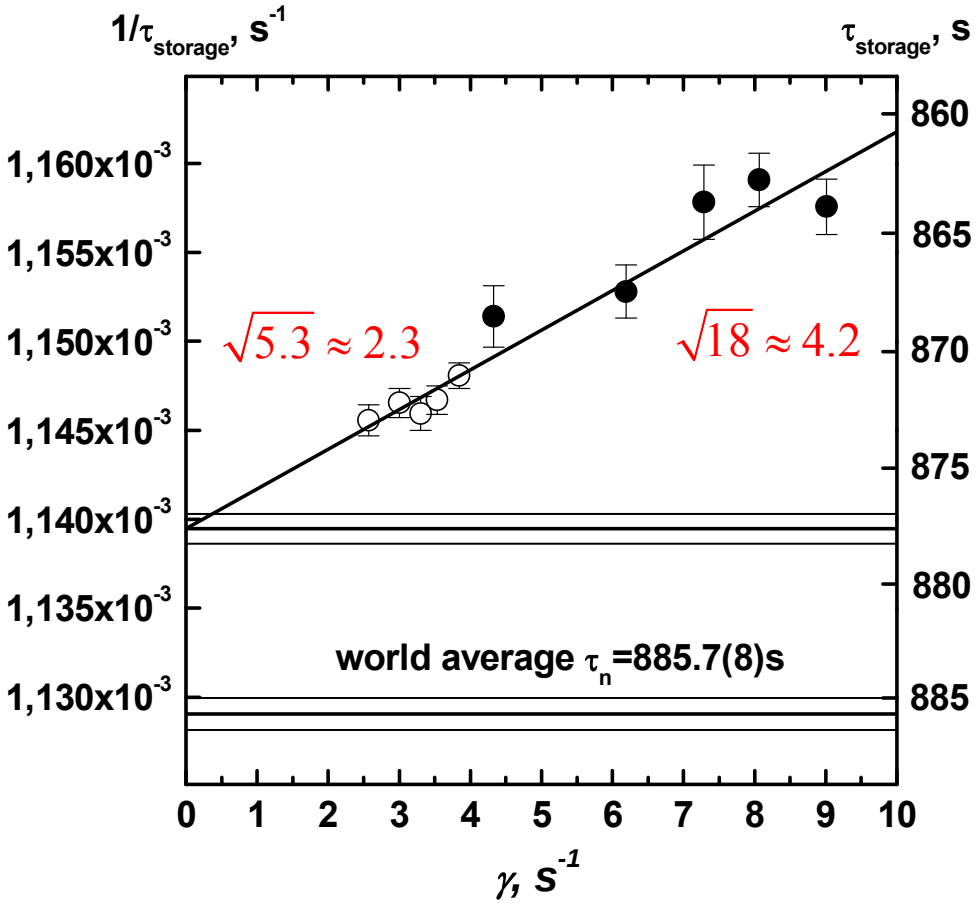


Improvement of statistical accuracy (0.7 s → 0.2 s)

Increasing of “wide” trap volume is 5.3.

Increasing of “narrow” trap volume is 18.

Improvement of statistical accuracy of neutron lifetime extrapolation is from $\Delta\tau_{stat}$= 0.7 s to $\Delta\tau_{stat}$≈ 0.2 s .

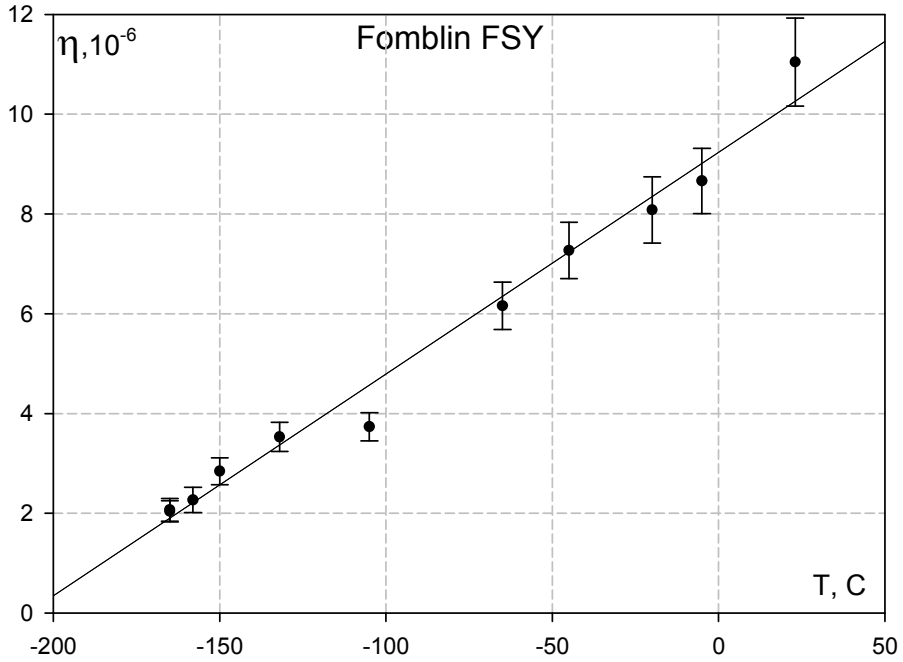


Trap coating

Low-temperature fully fluorinated polymer will deposit on the trap surface by evaporation in a vacuum:

- chemical name – perfluoropolyether;
- molecular weight M=2350;
- vapor pressure at r. t. is about $1.5 \cdot 10^{-3}$ mbar;
- pour temperature is about –100˚C;
- Fermi potential at r. t. is 102.8 neV;
- expected UCN loss factor is about $2 \cdot 10^{-6}$ at 190K [JETP 96 172 (2003)].

(V. Morozov et al.)

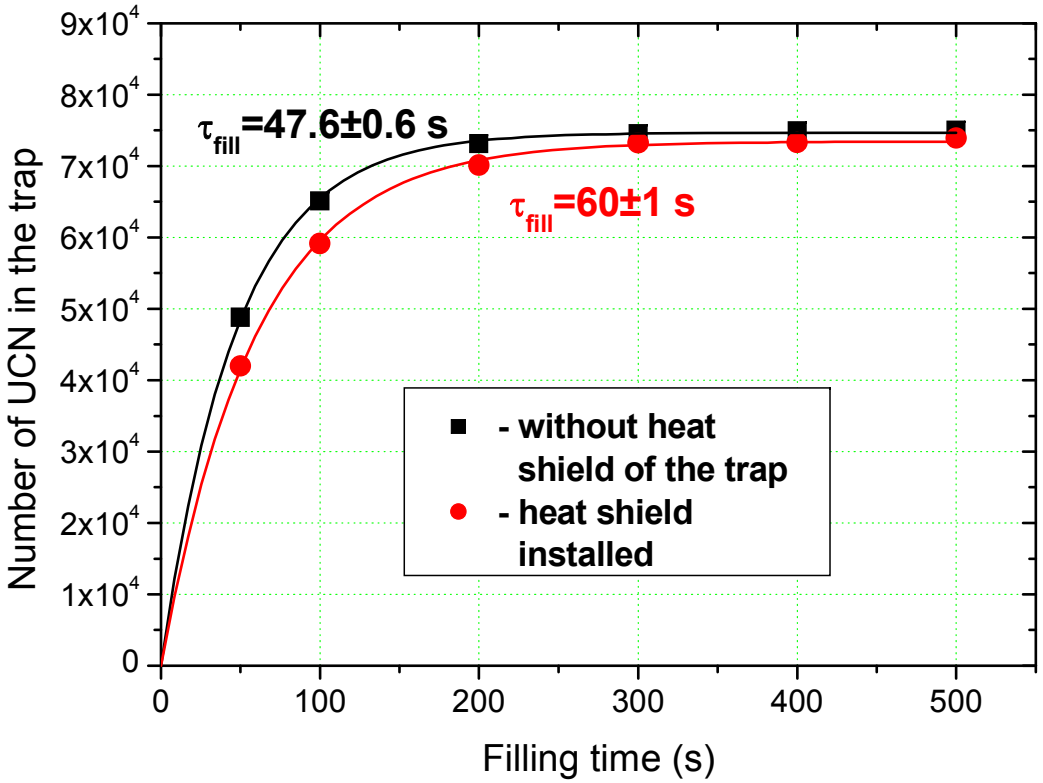


The temperature dependence of loss factor η for perfluoropolyether

Monte Carlo simulation of the trap filling

The bigger trap volume is lead to longer trap filling.

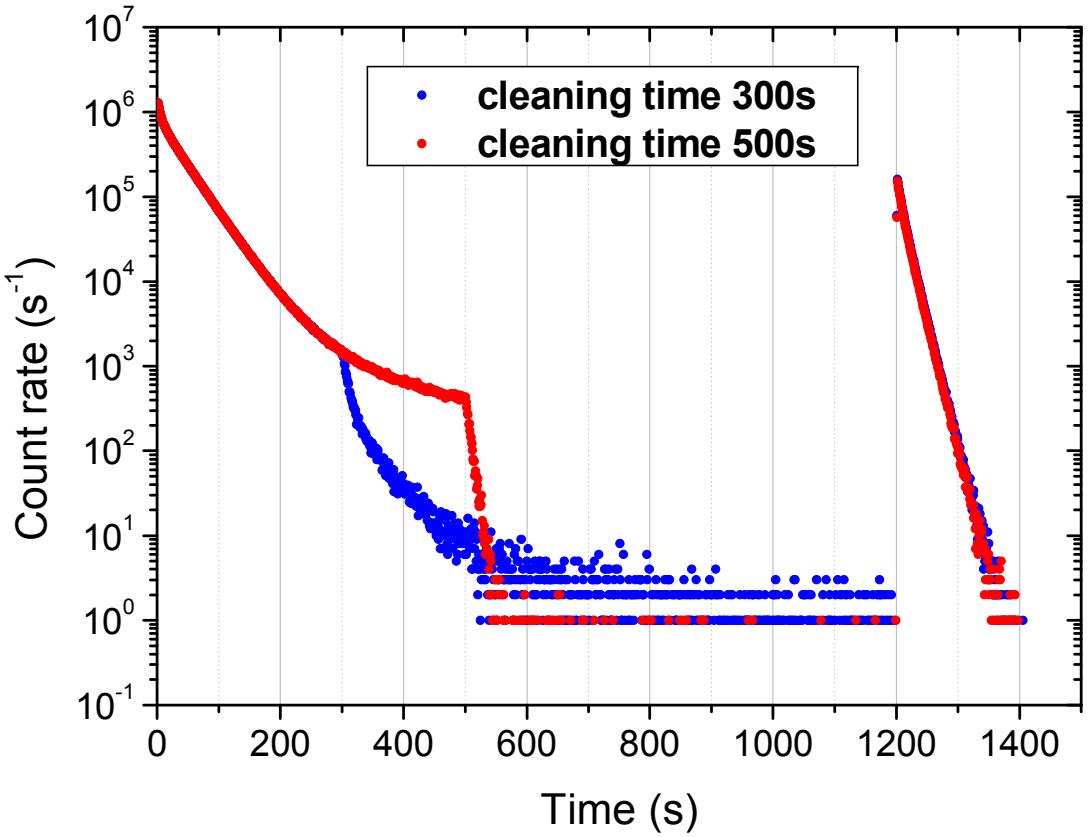
To keep the reasonable filling time of the trap we have to increase the diameter of neutron guide from 80 mm to 140 mm.



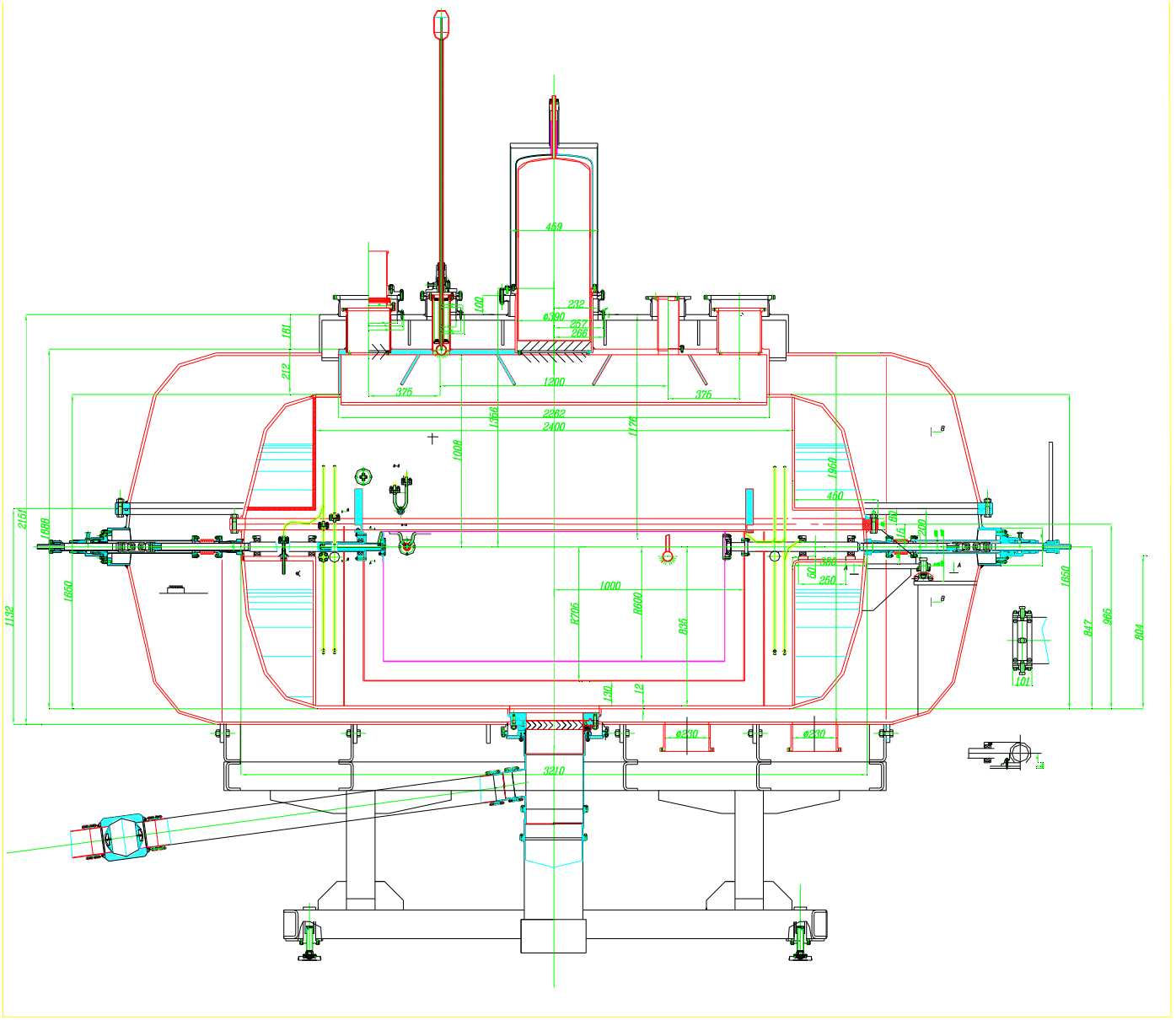
Monte Carlo simulation of leakage process of UCN exceeding the gravitational barrier of the trap

UCN storage time correction for leakage of UCN exceeding the gravitational barrier of the trap depends on cleaning time.

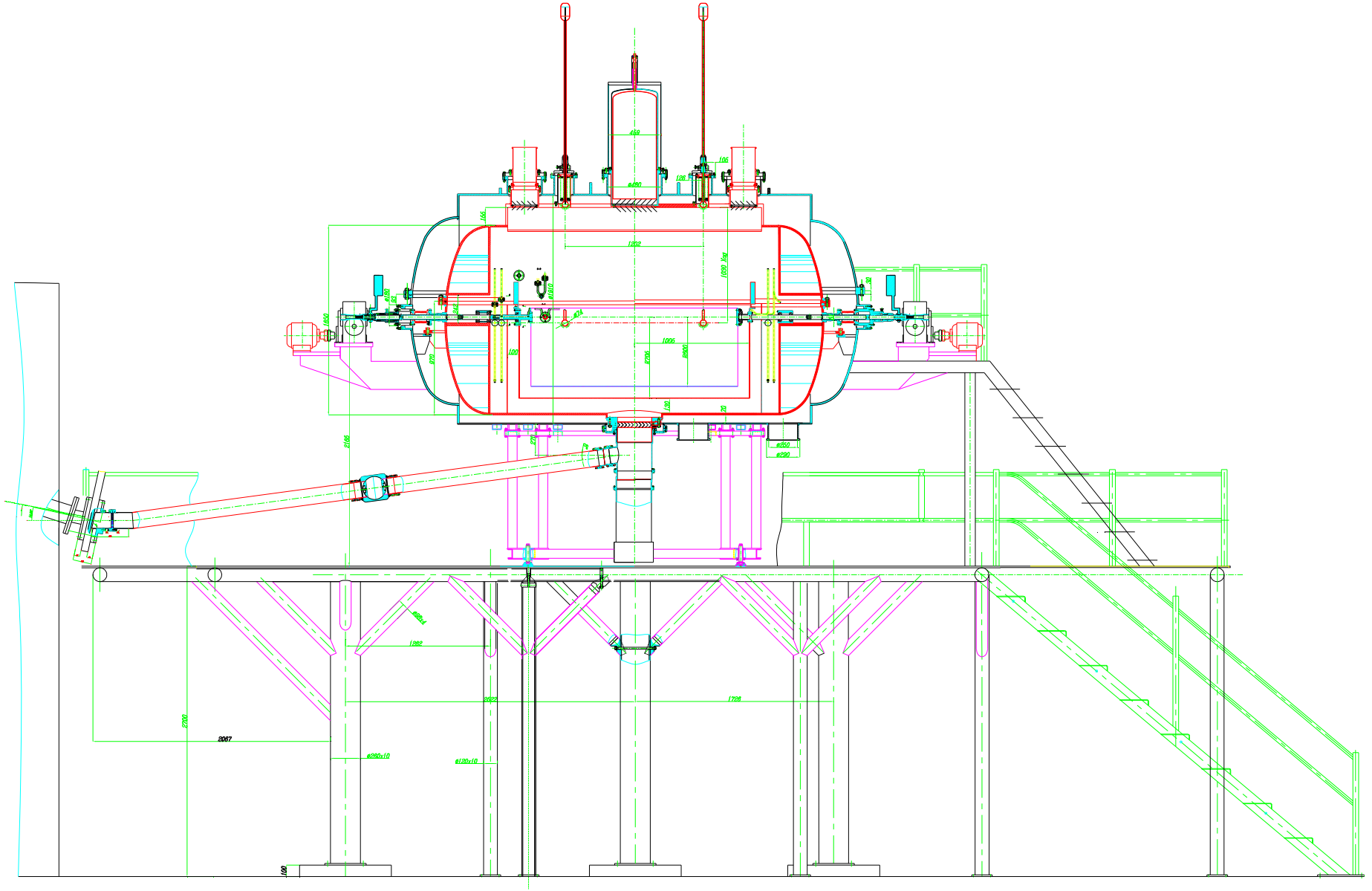
Cleaning time (s)	Correction (s)
300	0.7
500	0.01



Design of Big Gravitational Trap (general view)



Design of Big Gravitational Trap (general view on position PF2 MAM)



Preparation of vacuum vessel of “Gravitrap II”

Preparation of vacuum vessel of “Gravitrap II”

internal view

preparation of internal elements

Conclusion
(list of improvements)

1. Statistical accuracy 0.7 s → 0.2 s;
2. Vacuum correction 0.4 s → 0.04 s;
3. Measurement in two positions without disassembling;
4. Improvement of loss factor ? $2 \cdot 10^{-6} \rightarrow 10^{-6}$?
5. Expected accuracy: statistical ~ 0.2 s
   systematical < 0.1 s