Simulation of the experimental program with ultracold neutrons and neutrino at the PIK reactor

A.K. Fomin, A.P. Serebrov

NRC «Kurchatov Institute» - PNPI, Russia, Gatchina

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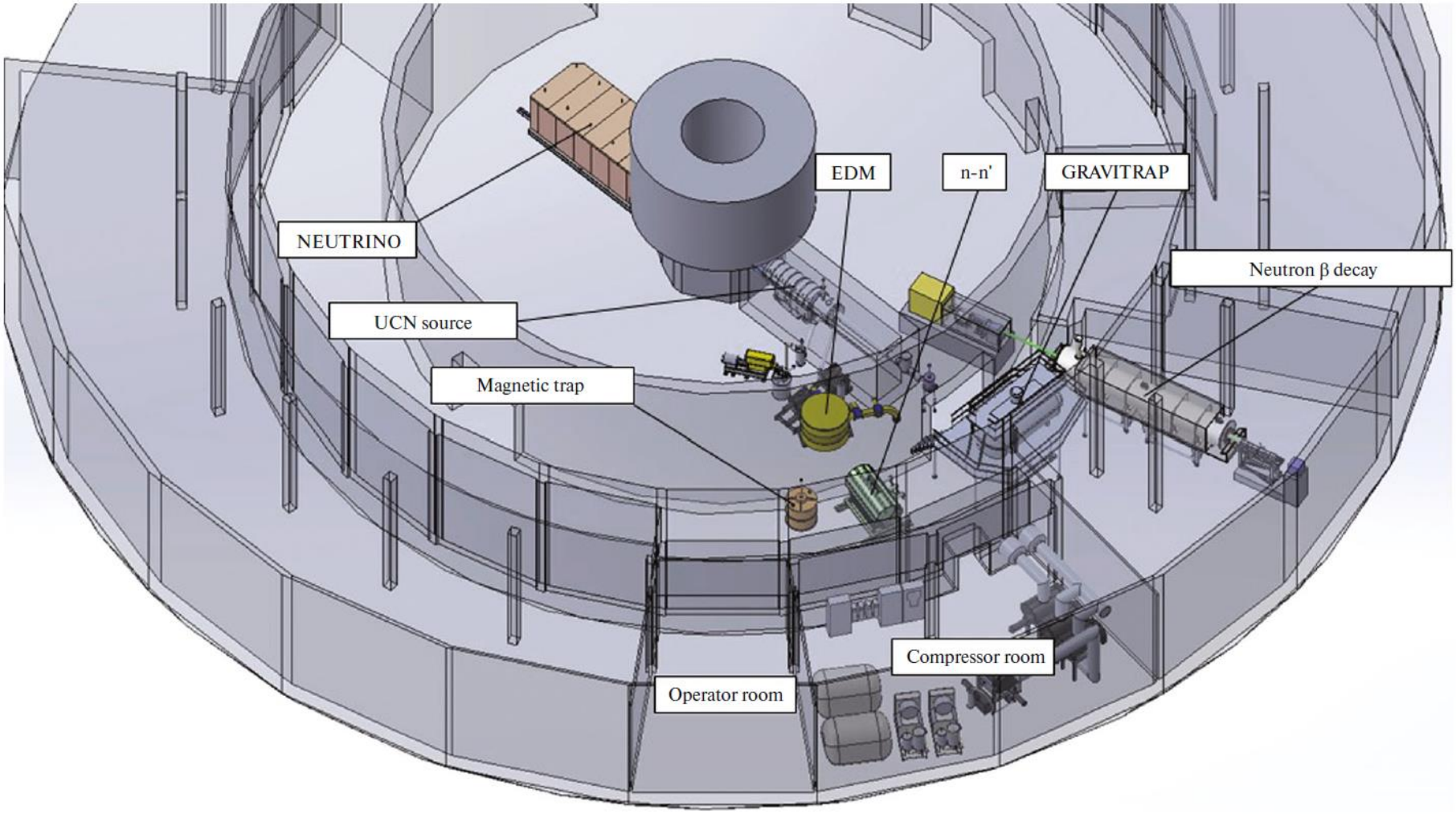
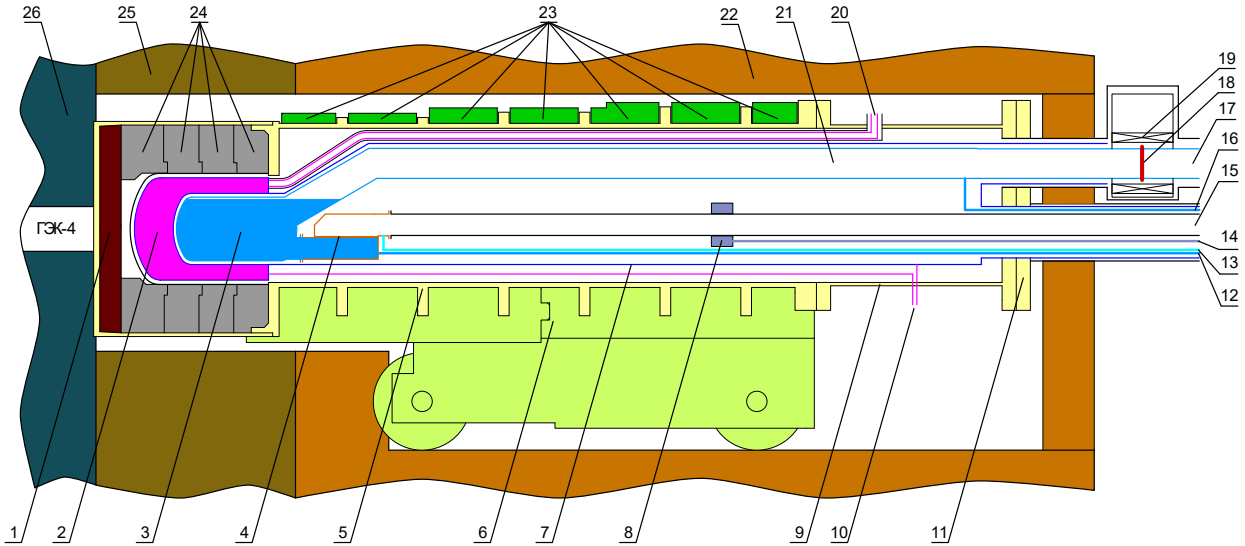
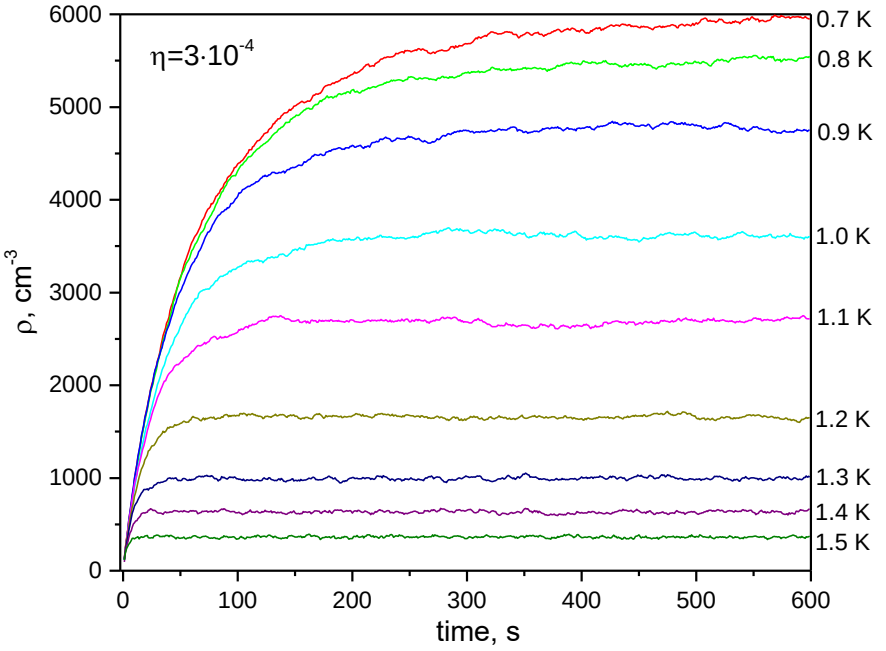
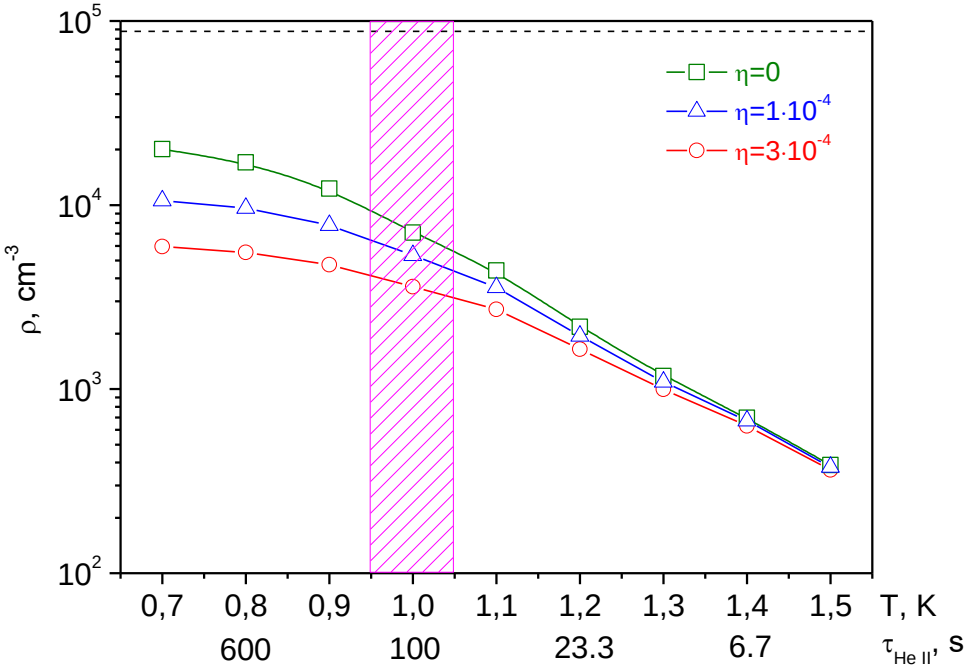
Experimental program with UCN and neutrino at the PIK reactor



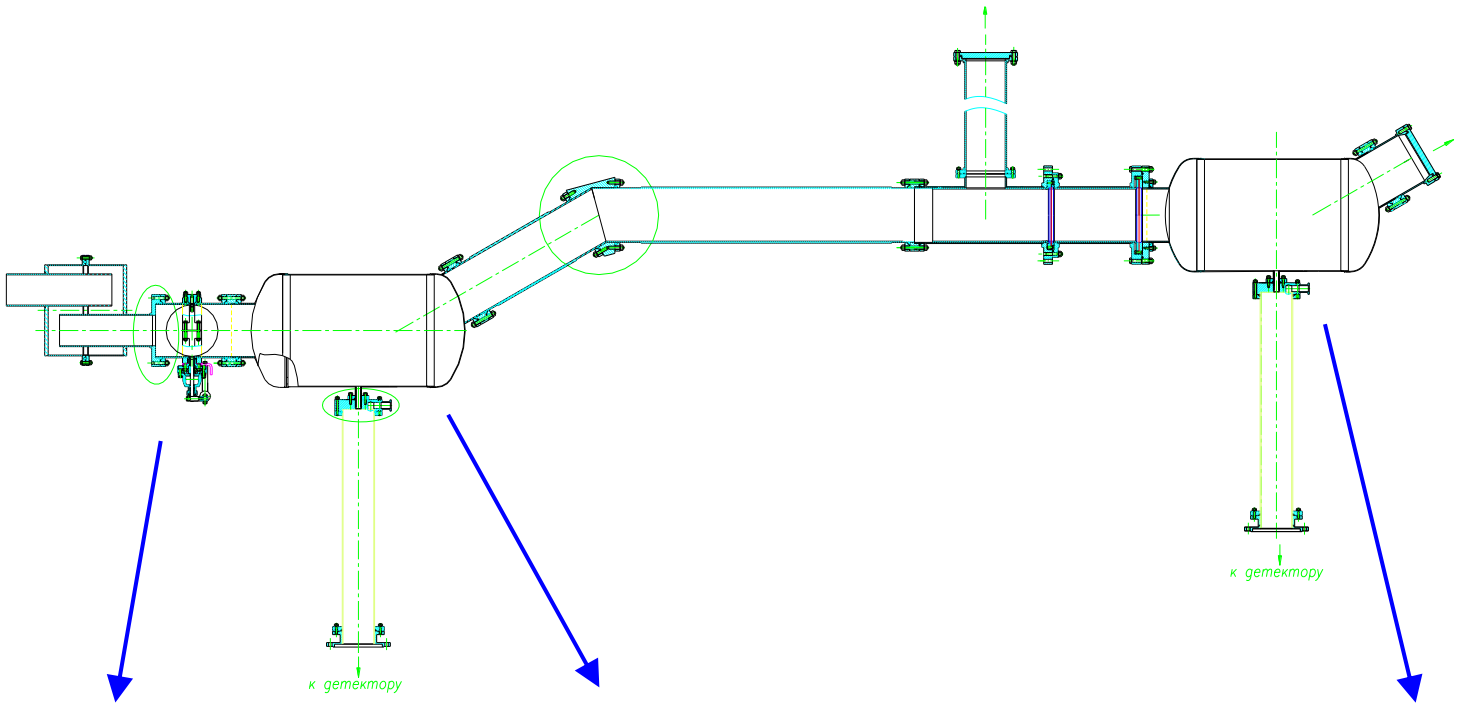
UCN source based on superfluid helium

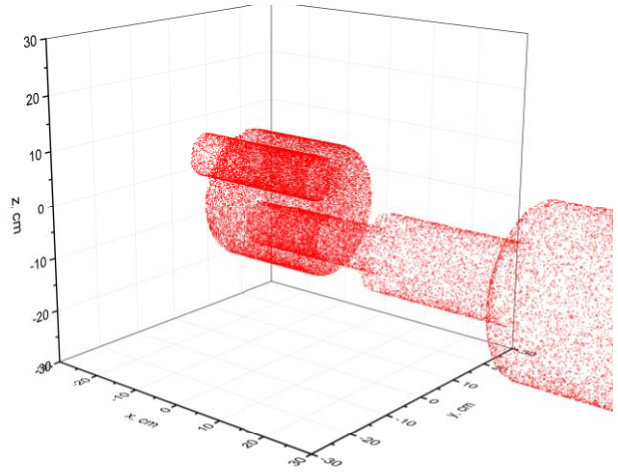


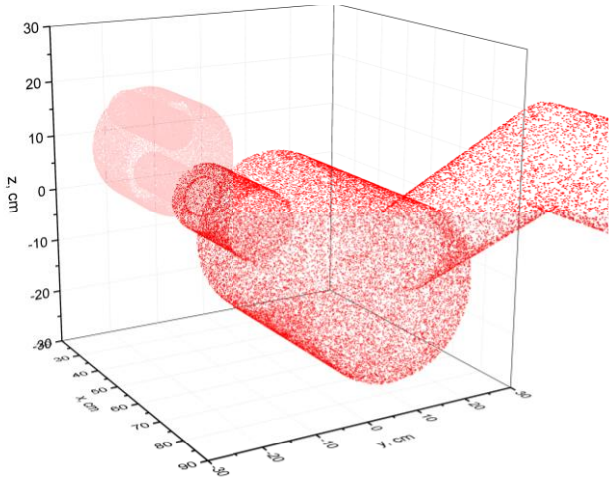


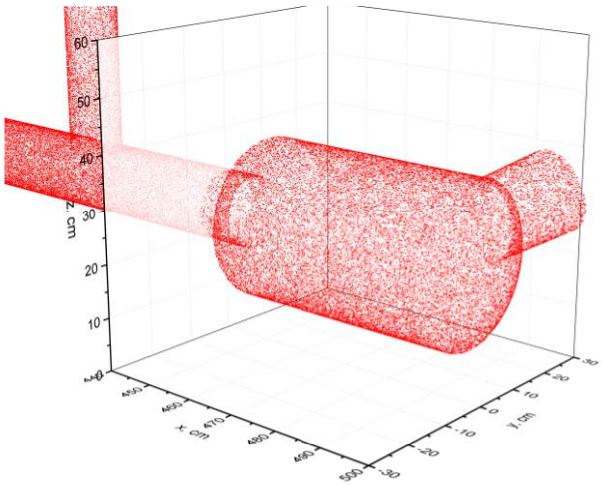


Test bench at ILL

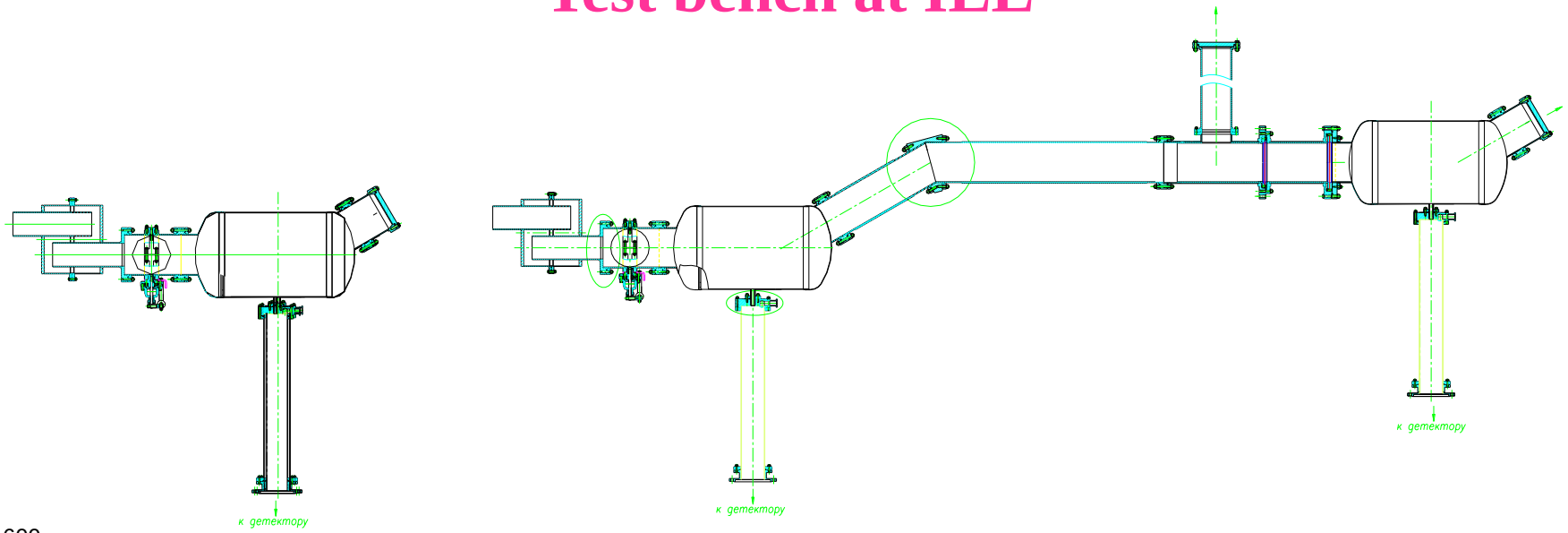


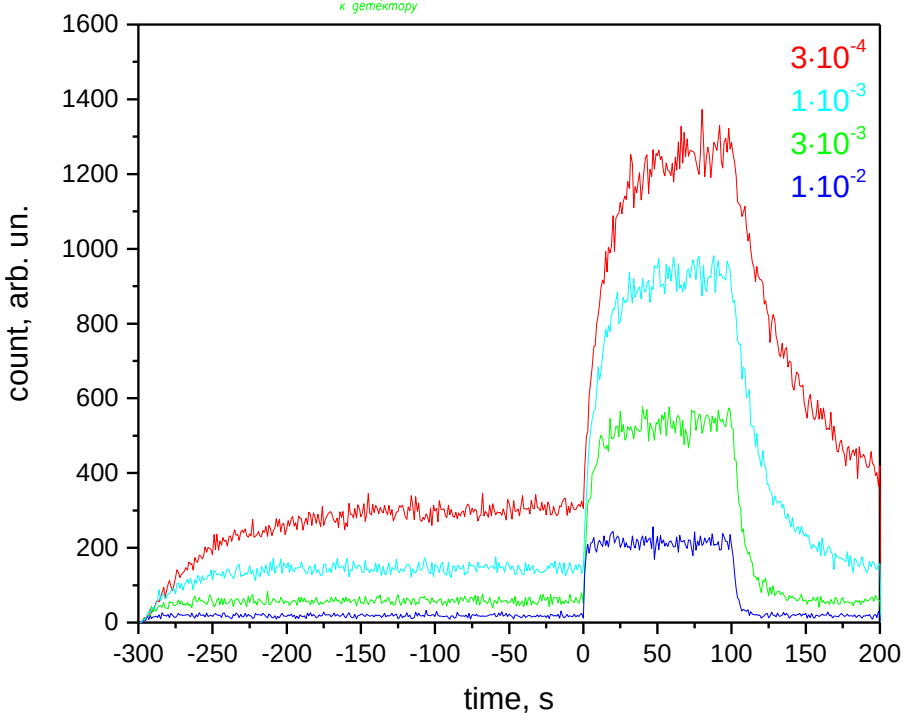


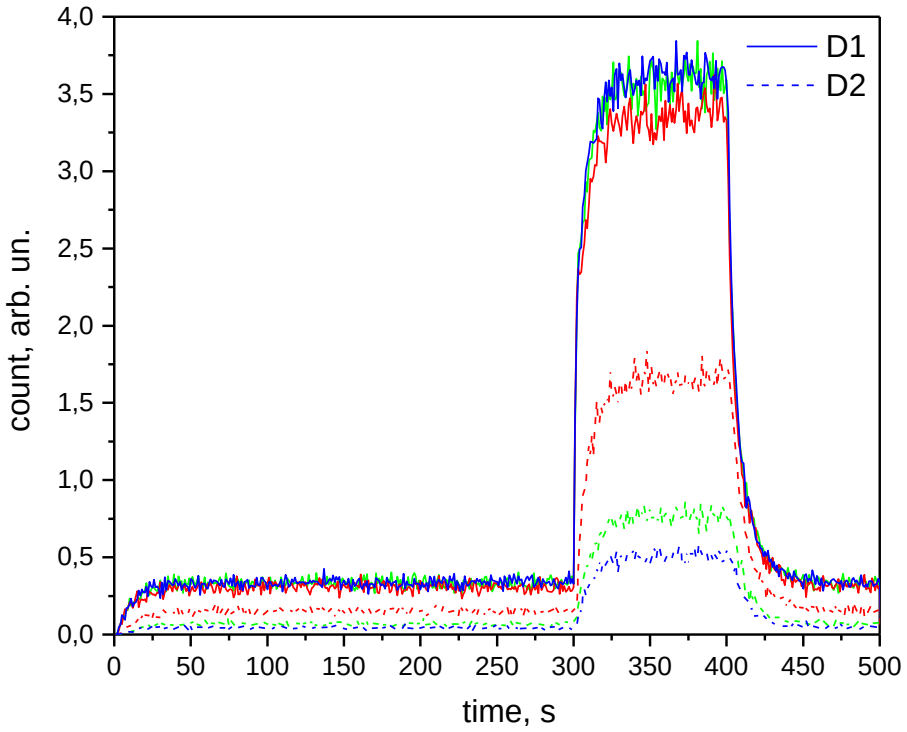




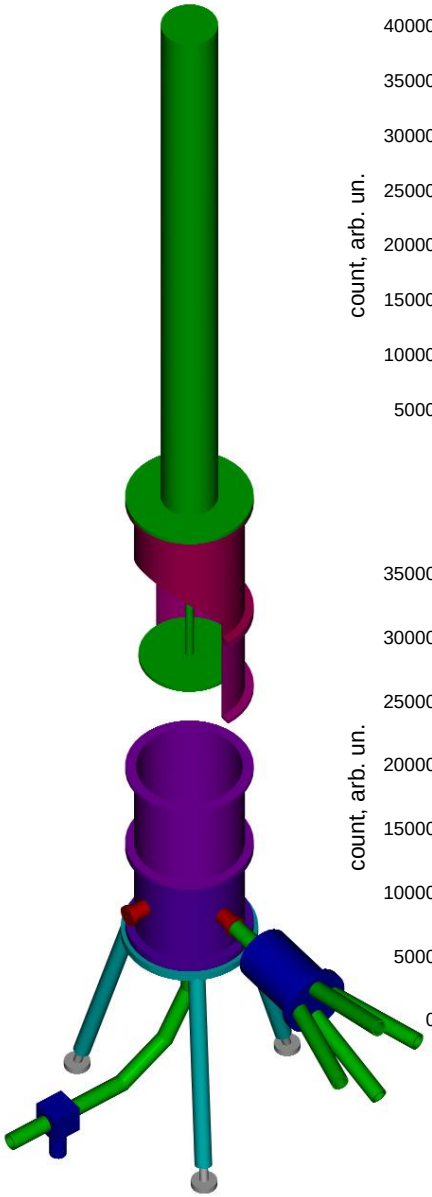
Test bench at ILL

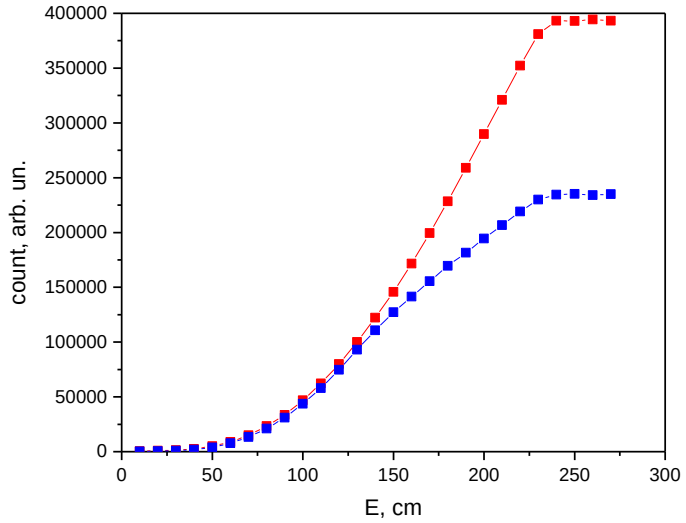


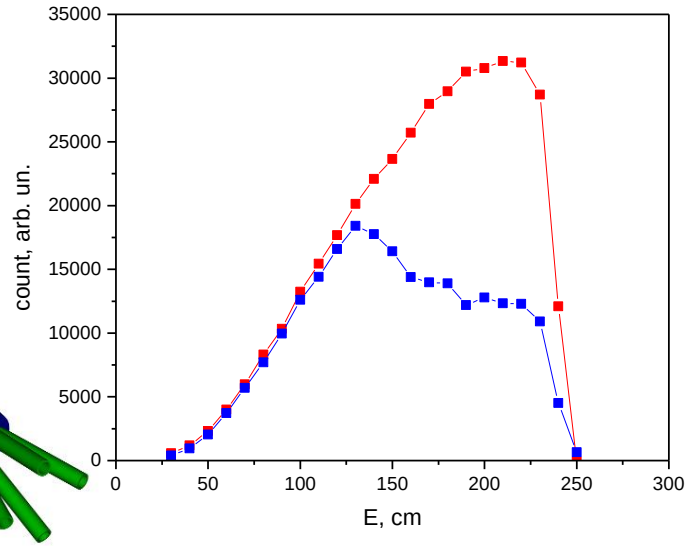


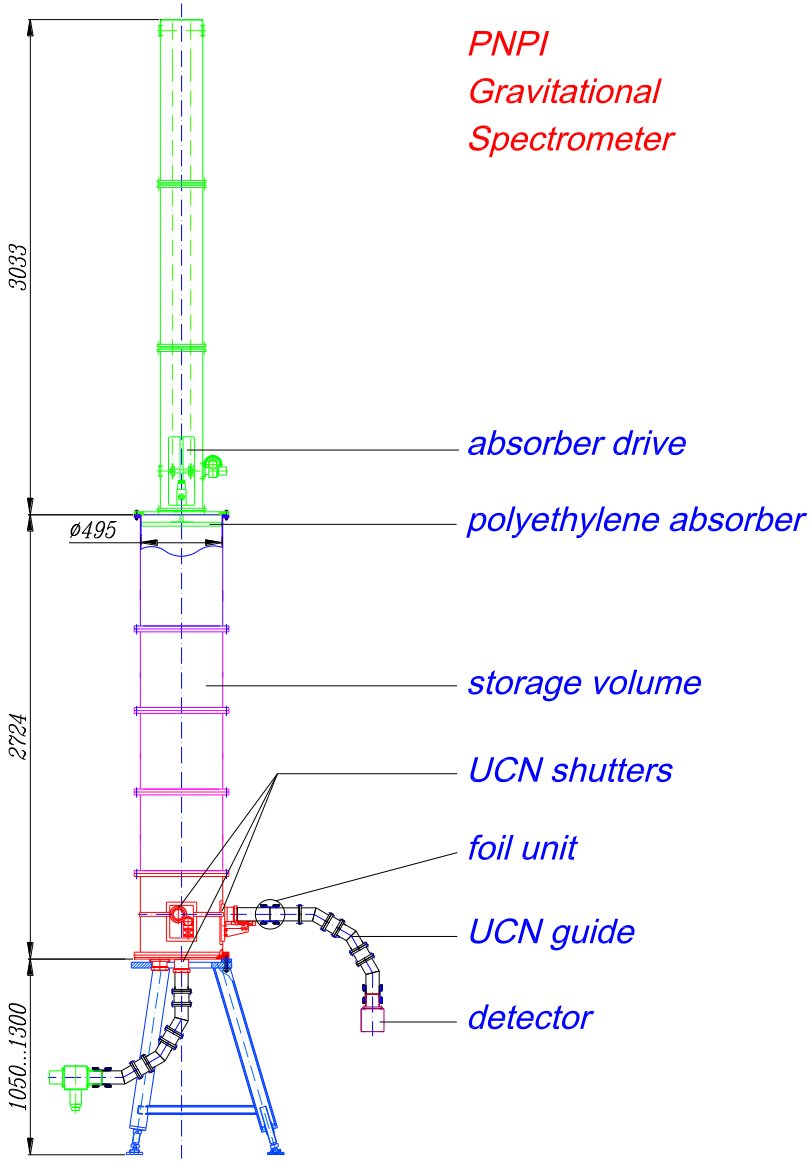


Gravitational spectrometer





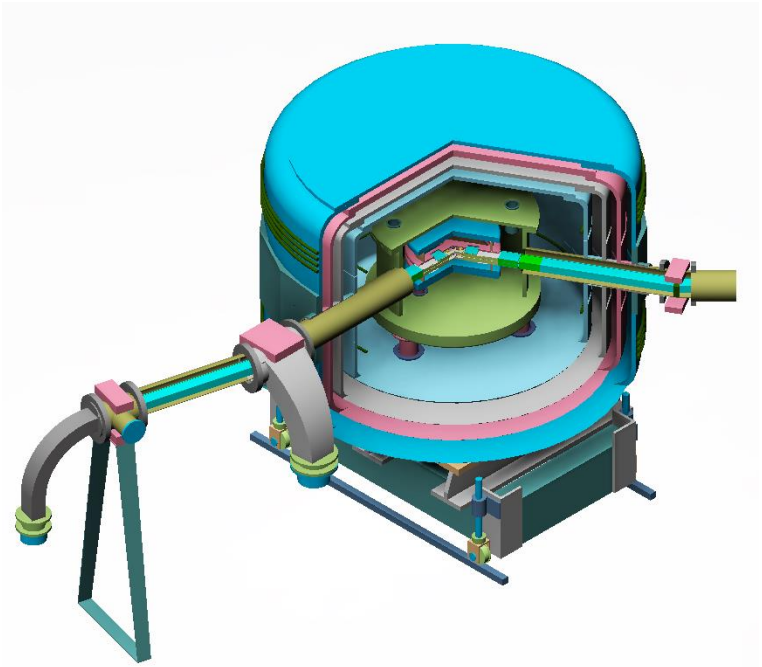




PNPI
Gravitational
Spectrometer

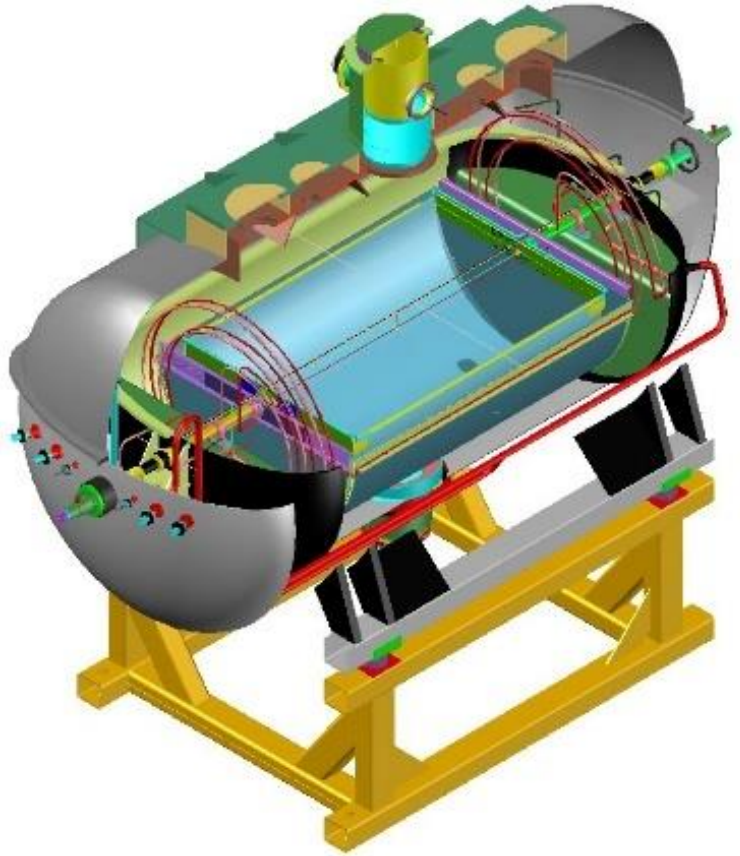
Experimental program with UCN

Neutron electric dipole moment



0-235 neV
35 l

Neutron lifetime



0-70 neV
1500 l

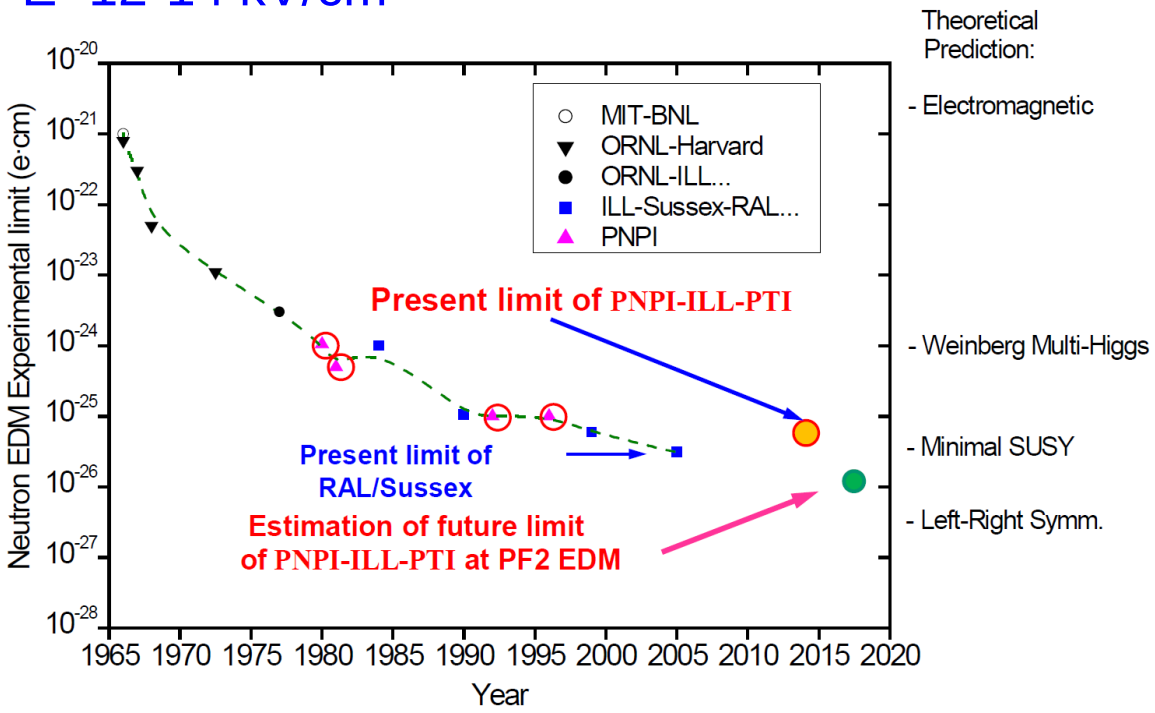
PNPI EDM spectrometer at ILL 2008-2014

Measurements of neutron EDM carried out at ILL reactor (Grenoble, France) on the PNPI experimental installation. The double-chamber magnetic resonance spectrometer with long holding of ultracold neutrons is used. The results obtained determine the upper limit for neutron EDM at 90% confidence level

$|d_n| < 5.5 \cdot 10^{-26}$ e·cm

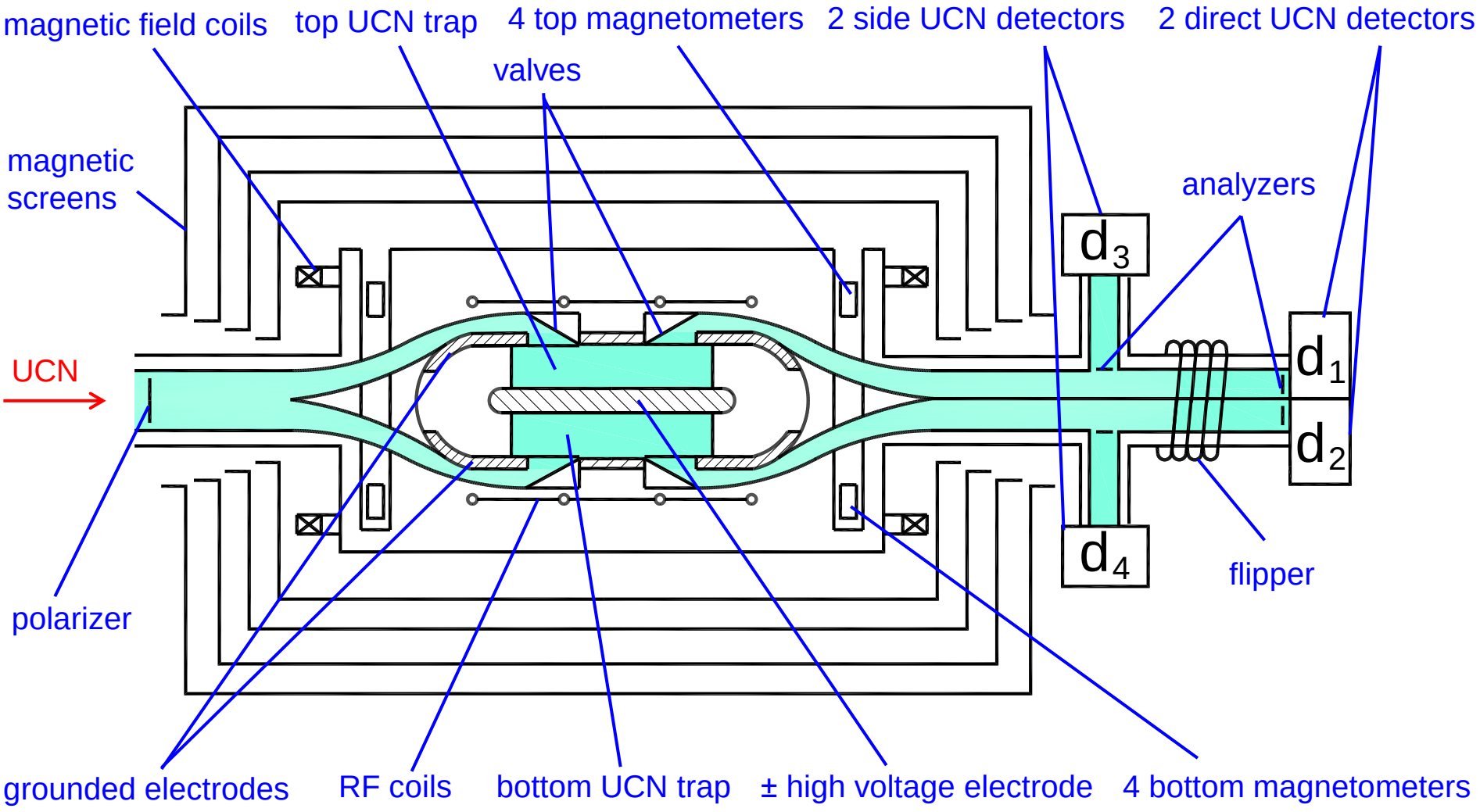
$\delta d_n \sim 1.7 \cdot 10^{-25}$ e·cm/day, $\rho_{ucn\ at\ entrance} \sim 4\ cm^{-3}$

E=12-14 kV/cm

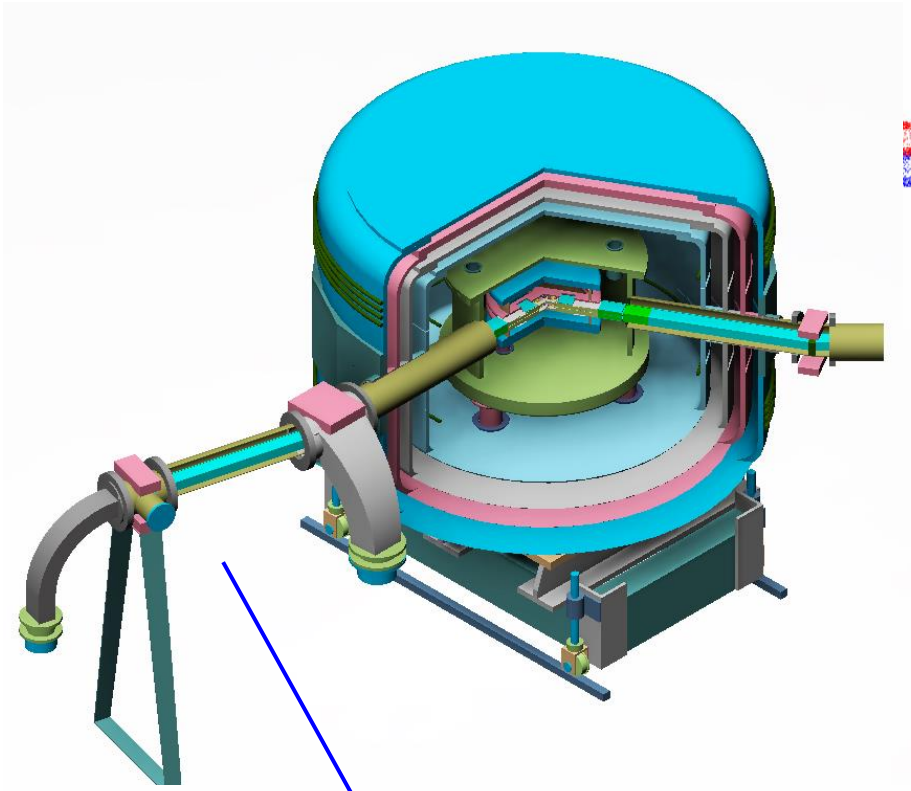


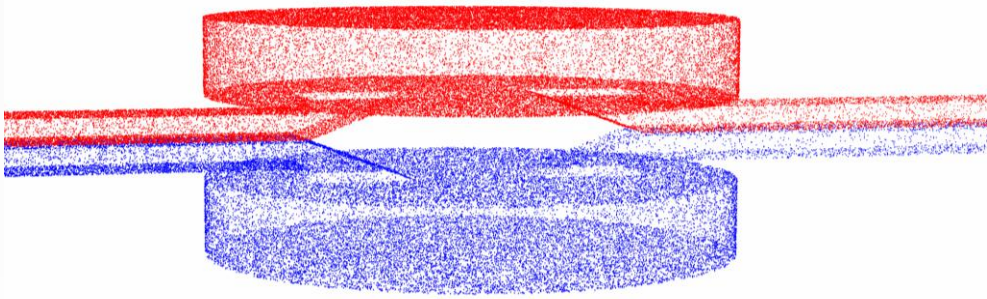
A.P. Serebrov et al., Phys. Rev. C 92 (2015) 055501

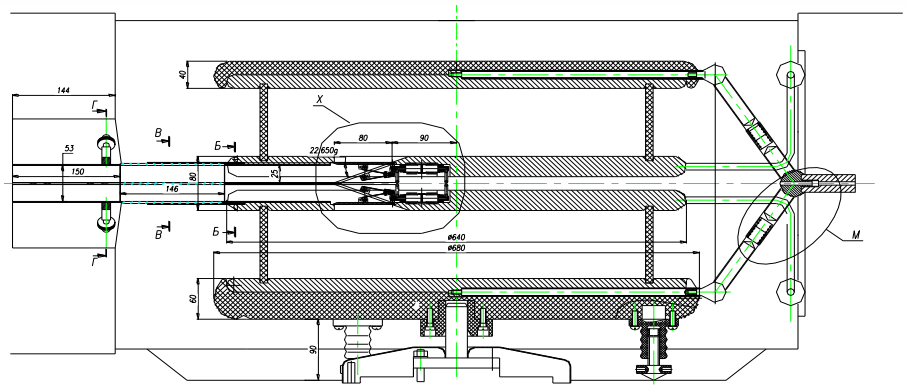
Scheme of EDM spectrometer

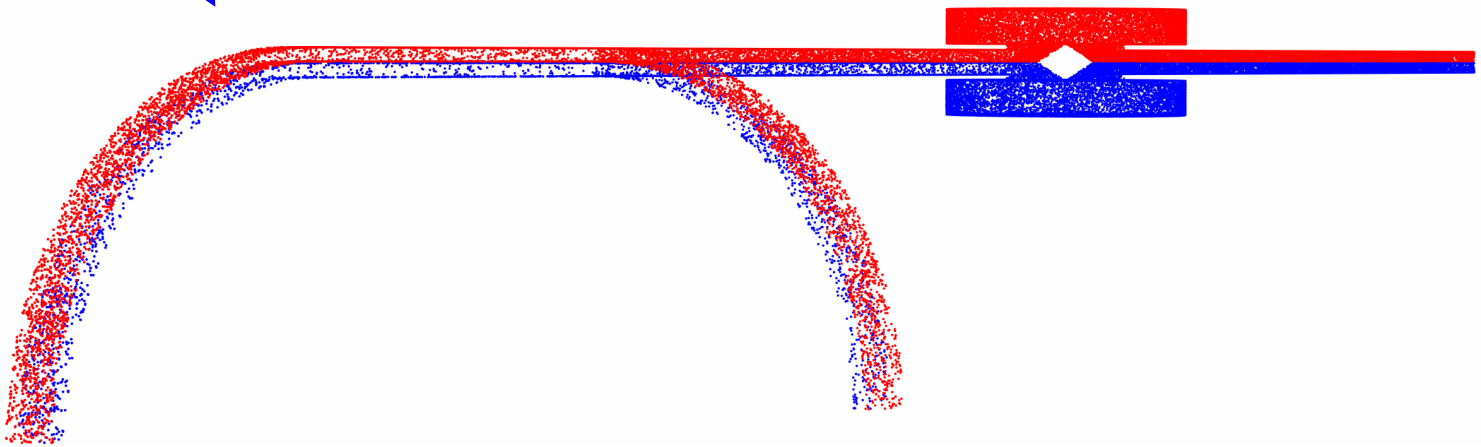


New scheme of EDM spectrometer

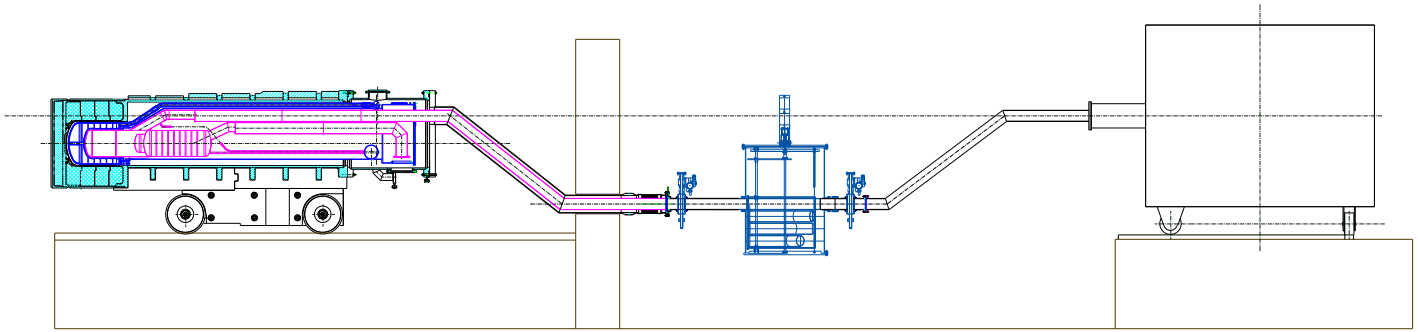


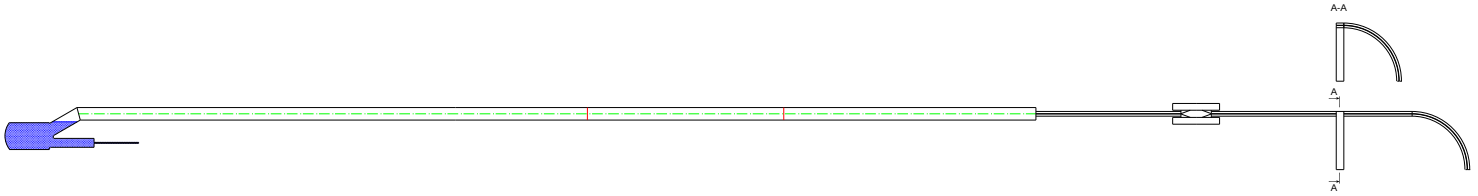


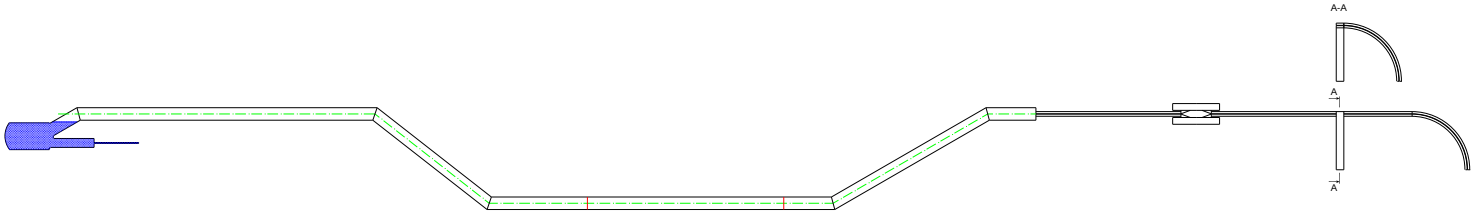




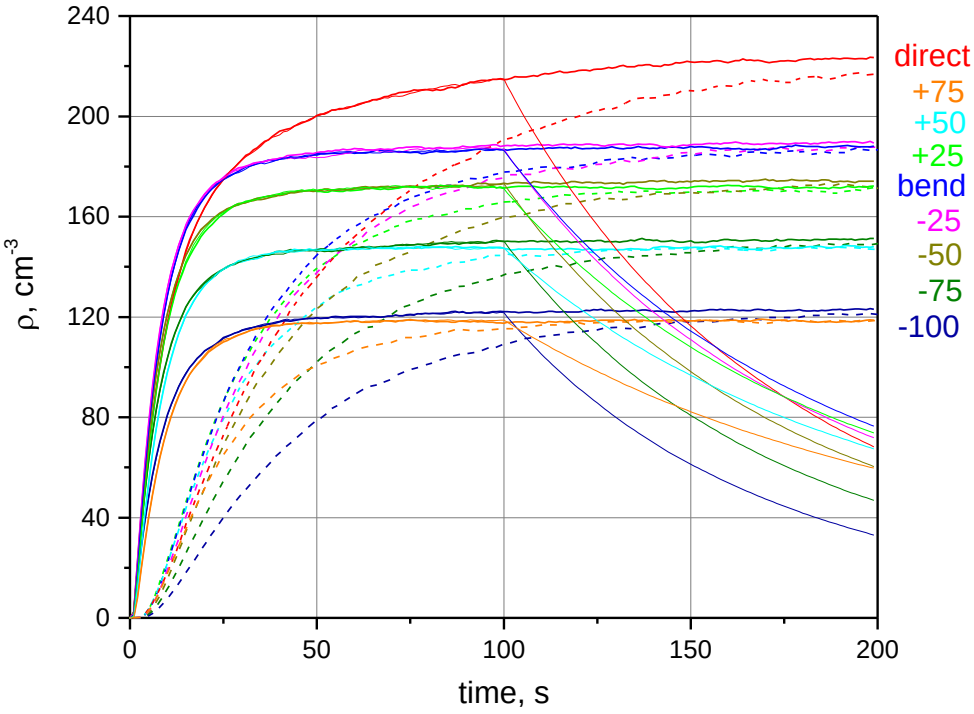
Calculational scheme

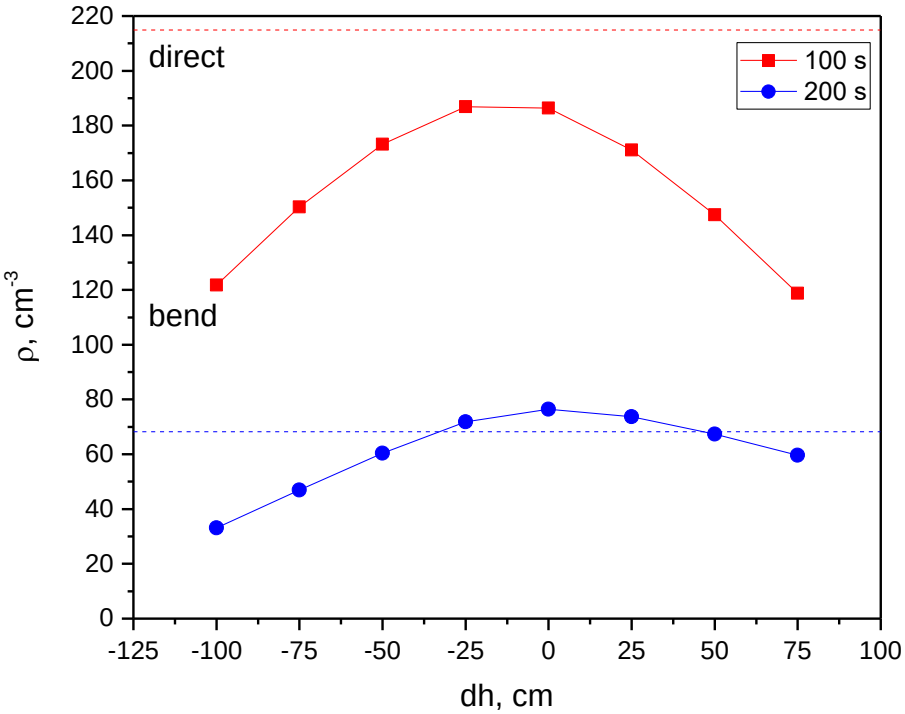






MC simulation





EDM experiment at the PIK reactor

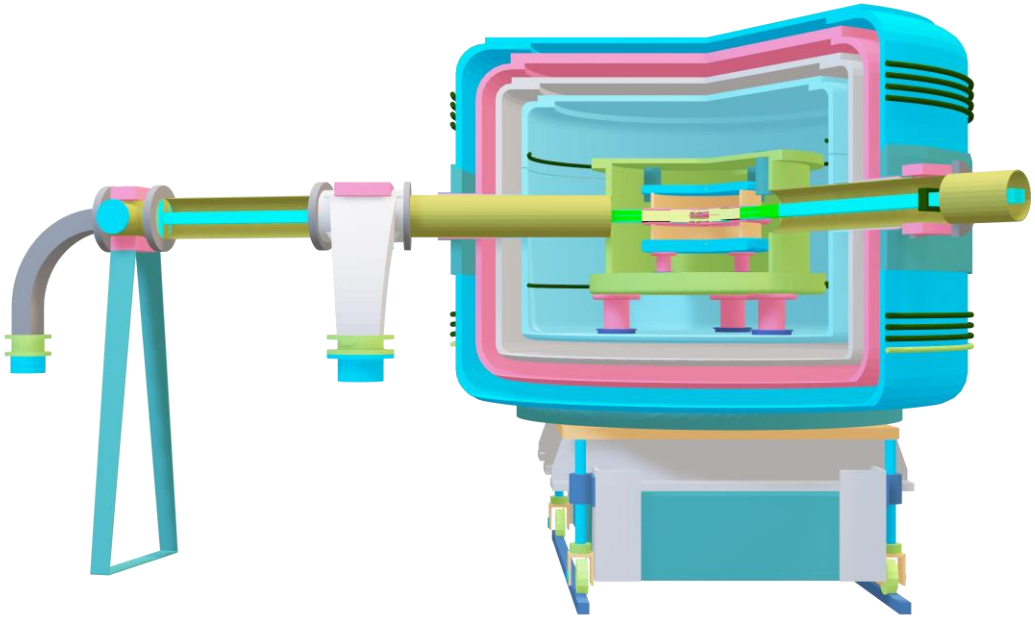
$\delta d_n \sim 1.7 \cdot 10^{-25}$ e·cm/day => $\delta d_n \sim 1 \cdot 10^{-25}$ e·cm/day

E=12-14 kV/cm => 27 kV/cm *Technical Physics 64 (2019) 436*

at ILL with $\rho_{ucn\ at\ entrance} \sim 4$ cm^{-3}

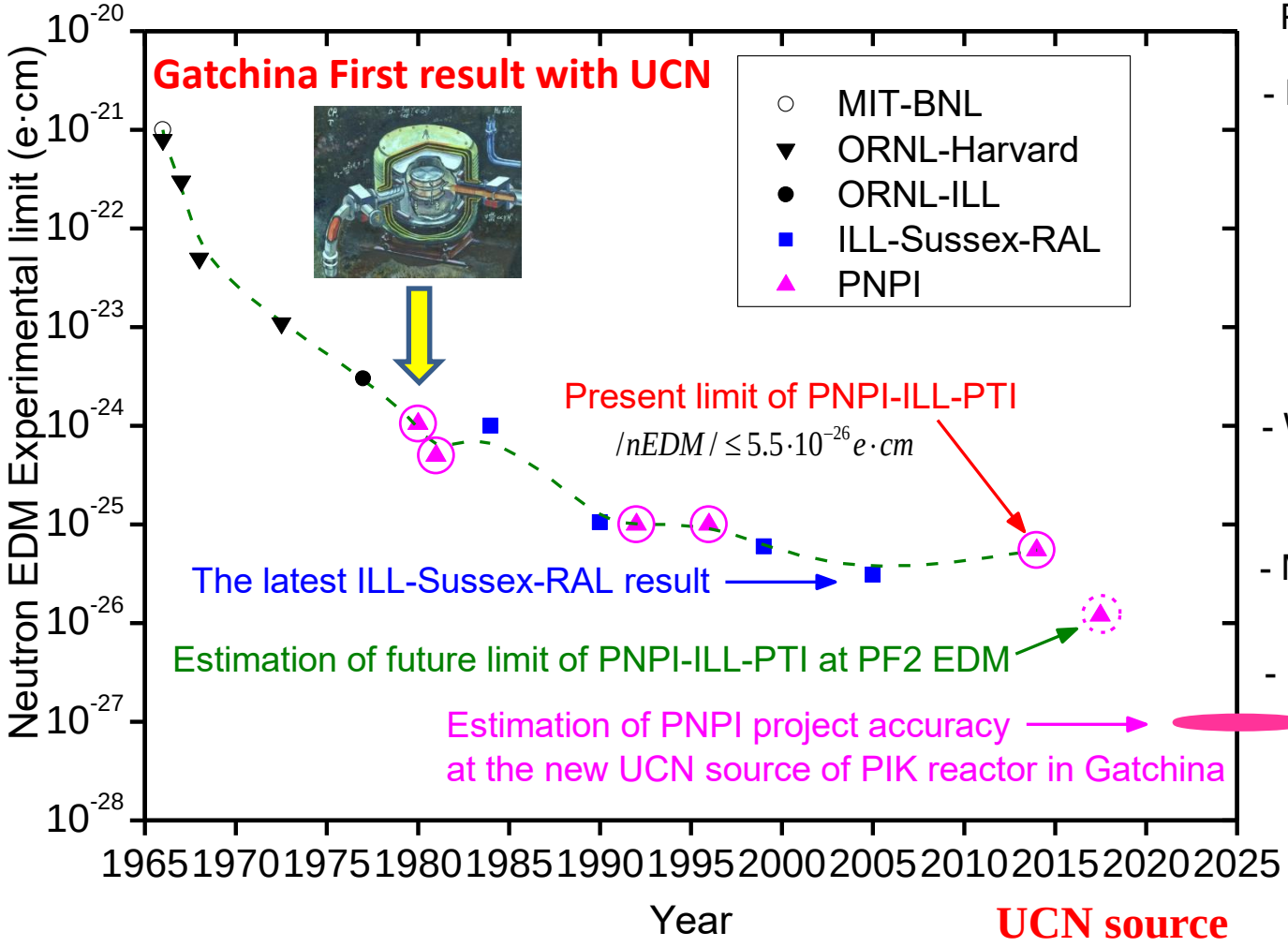
$\delta d_n \sim 1.5 \cdot 10^{-26}$ e·cm/day at PIK with $\rho_{ucn} \sim 200$ cm^{-3}

$\delta d_n \sim 1 \cdot 10^{-27}$ e·cm/year



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

CP-violation and search for neutron EDM

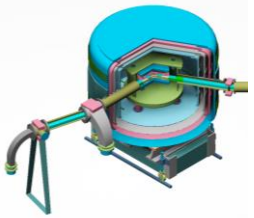


Theoretical Prediction:

- Electromagnetic
- Weinberg Multi-Higgs
- Minimal SUSY
- Cosmology
- Left-Right Symm.

$10^{-27}\, e \cdot cm$

UCN source at PIK reactor

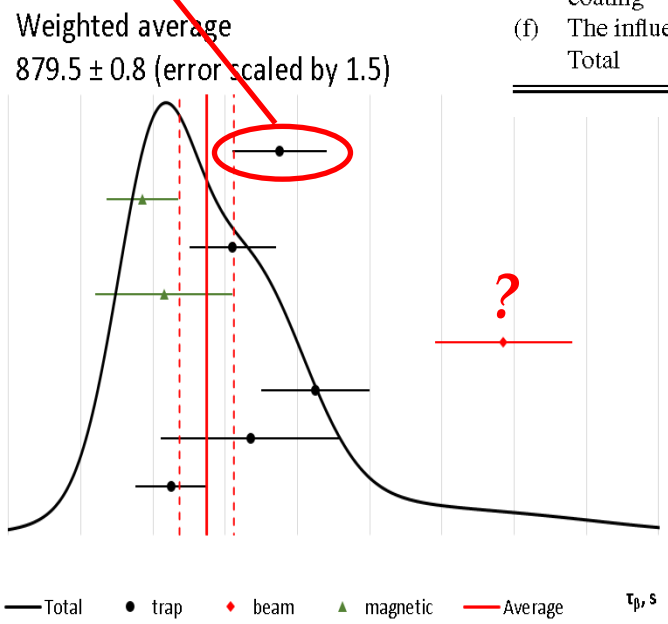


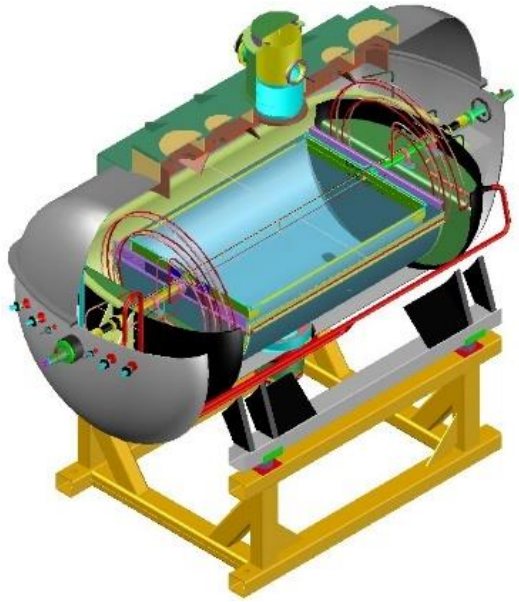
Neutron lifetime measurement with big gravitational trap

$$\tau_n = 881.5 \pm 0.7_{stat} \pm 0.6_{syst}\ s$$

TABLE IV. List of systematic effects.

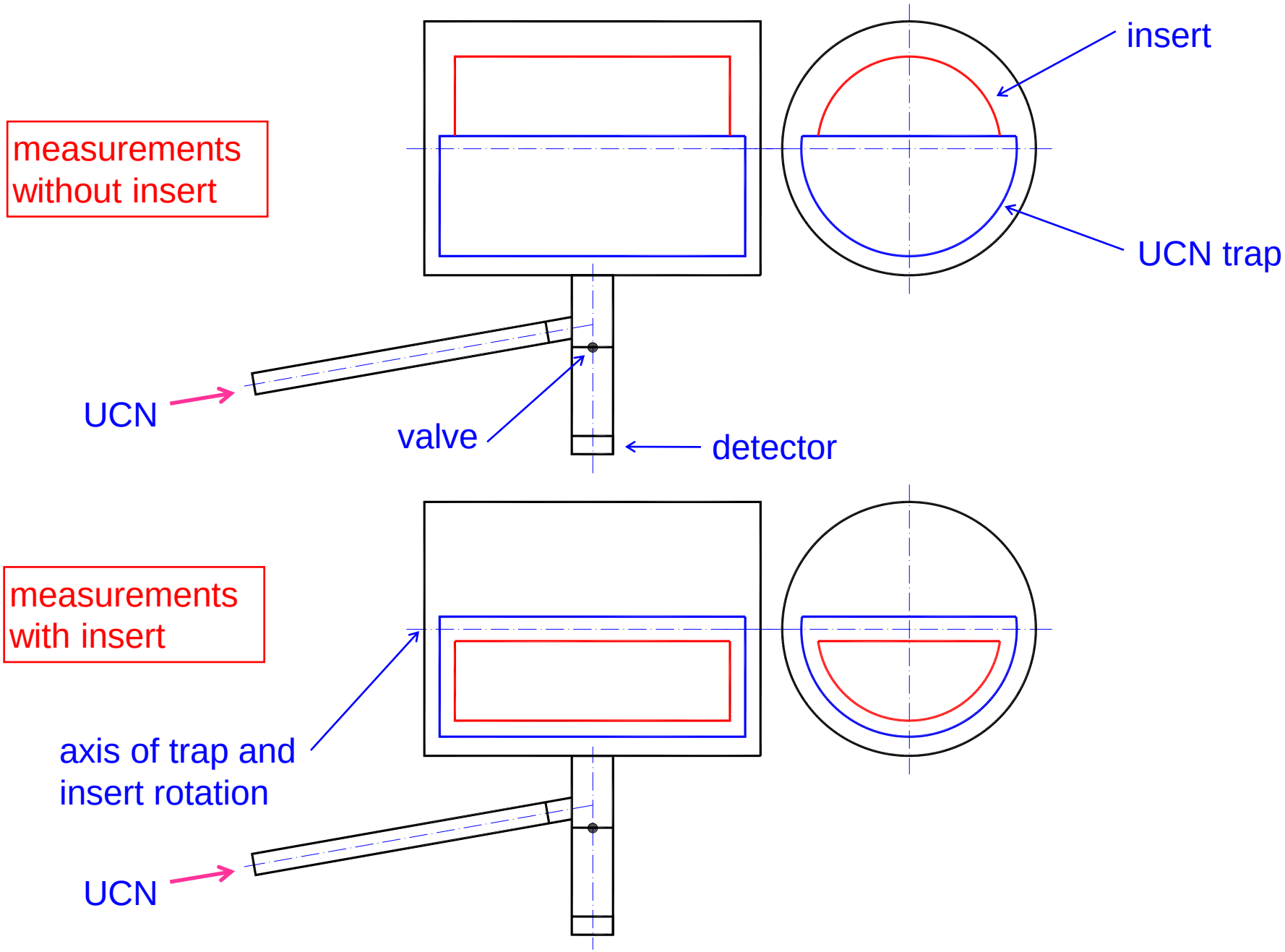
	Systematic effect	Value (s)
(a)	Uncertainty of shape of function μ(E)	±0.3
(b)	Uncertainty of trap dimensions (3 mm for diameter 1400 mm)	±0.15
(c)	Uncertainty of extrapolation method	±0.1
(d)	Uncertainty of trap angular position (2°)	±0.1
(e)	Uncertainty of difference for trap and insert coating	±0.5
(f)	The influence of the residual gas	0.2 ± 0.02
	Total	0.2 ± 0.6



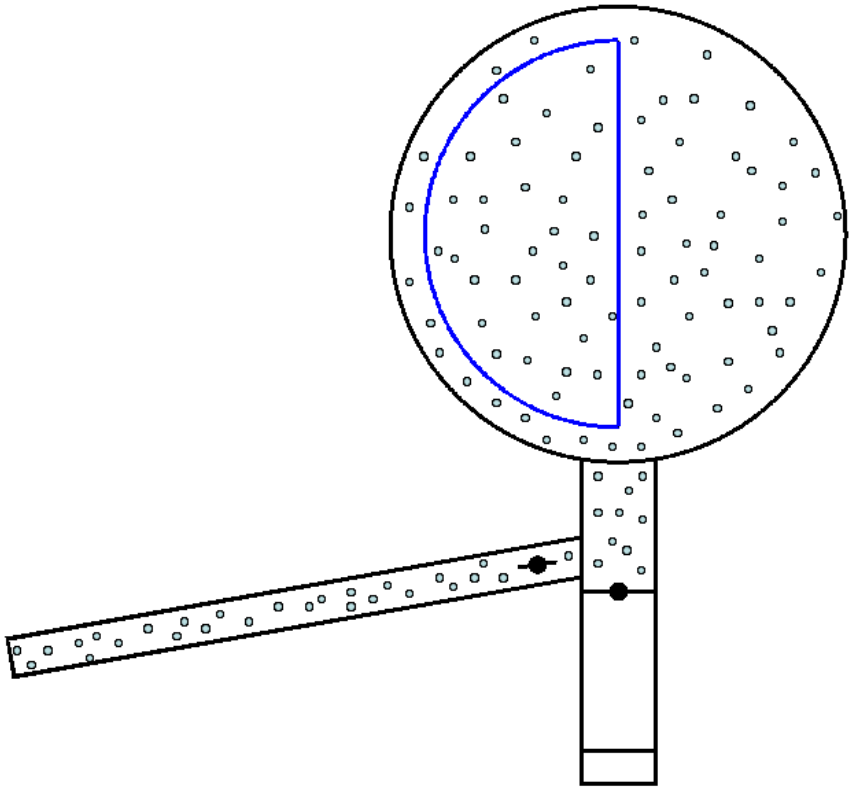


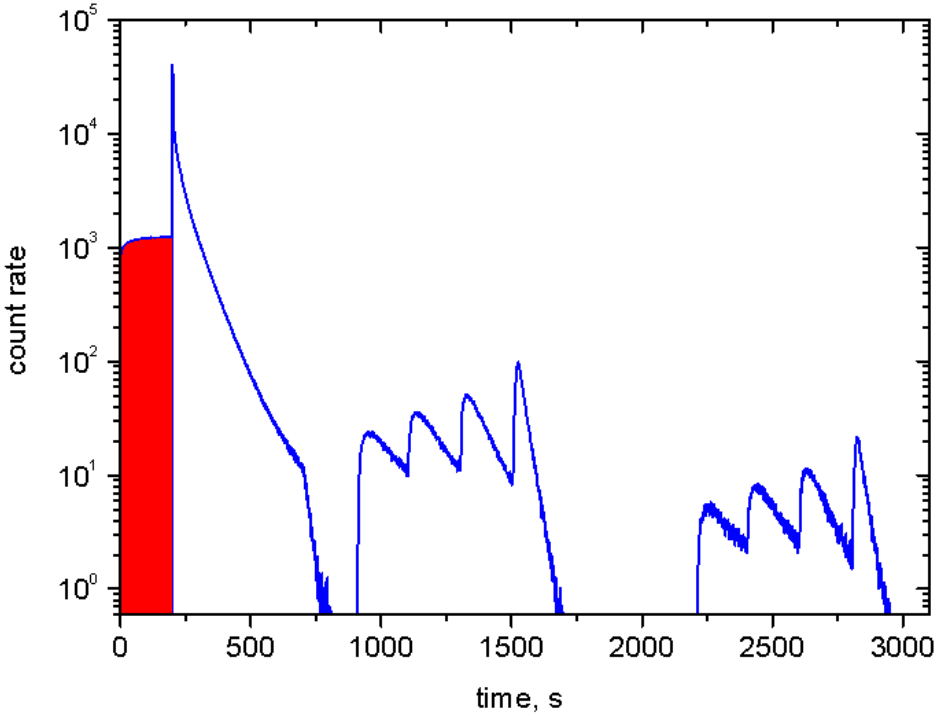
A.P. Serebrov et al., Phys. Rev. C 97 (2018) 055503

Scheme of setup



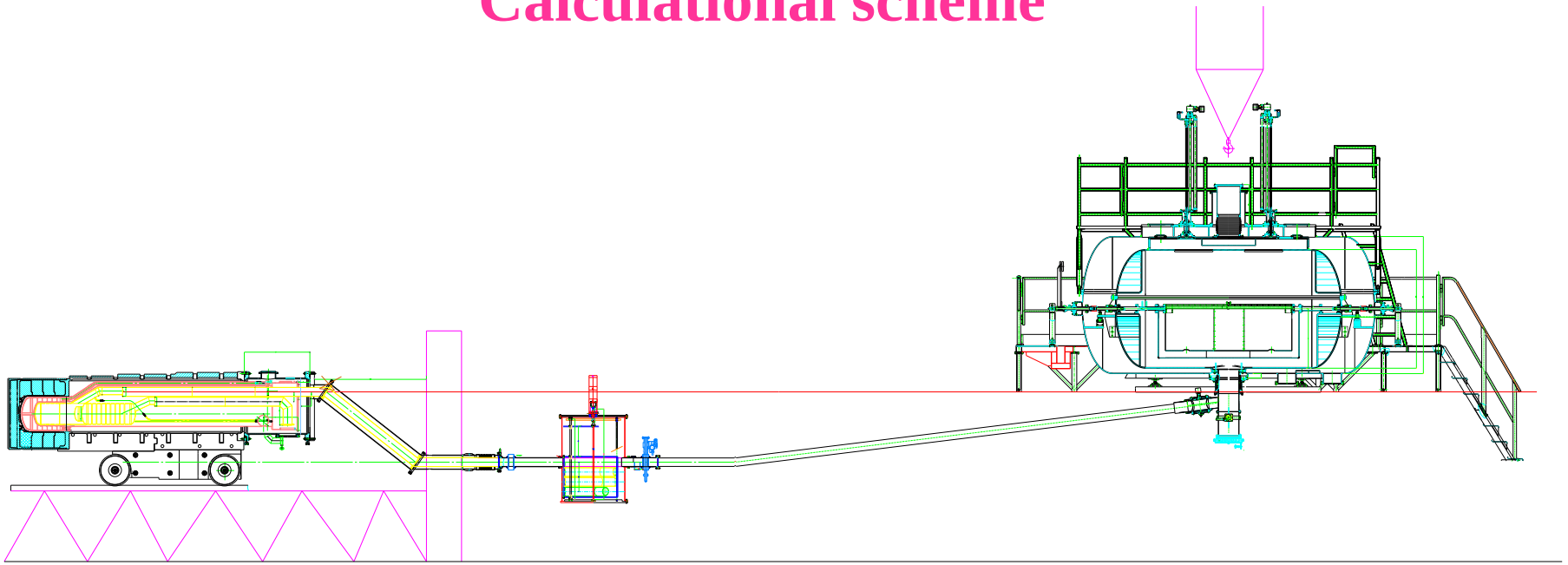
Measurement process

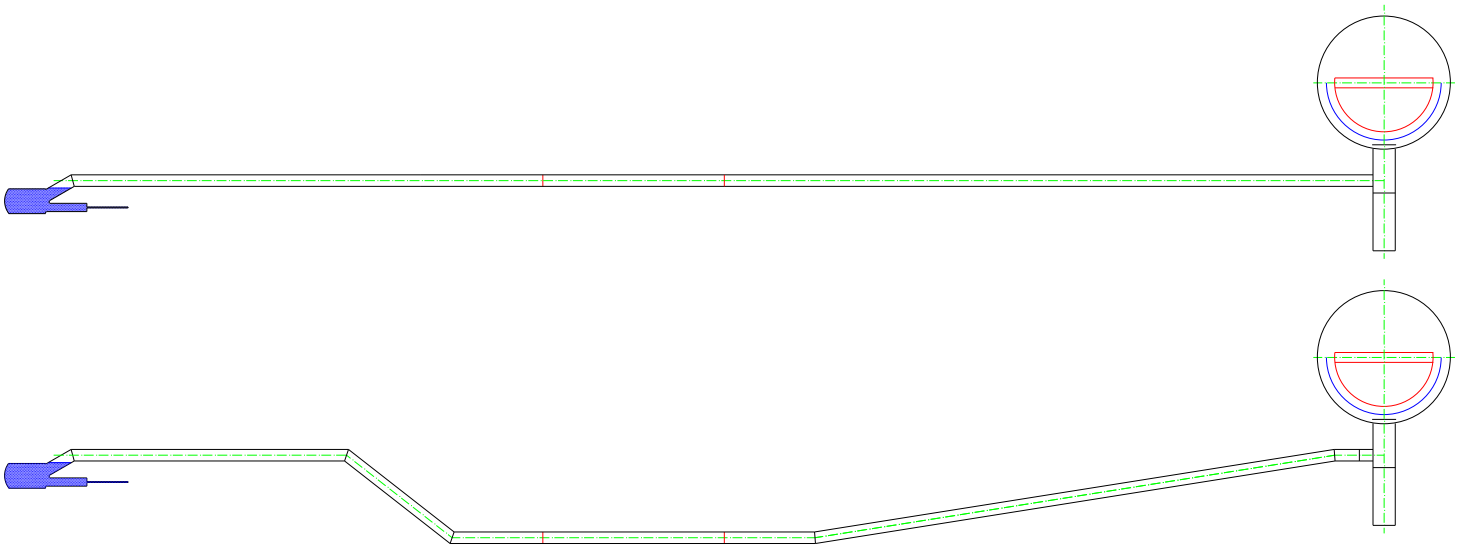




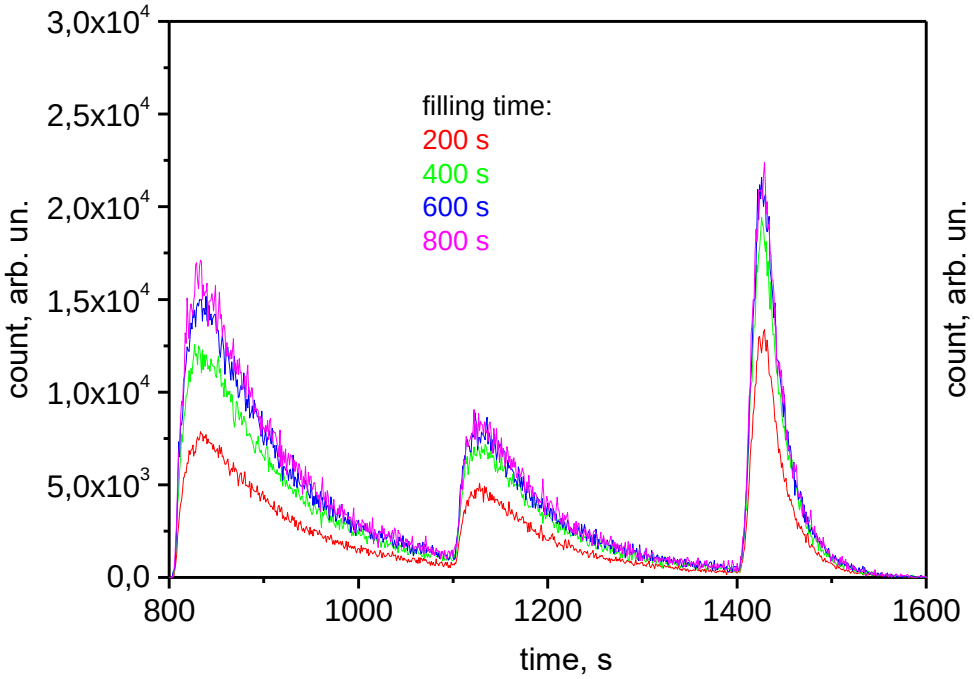
Filling of the trap with UCN: θ=90°.

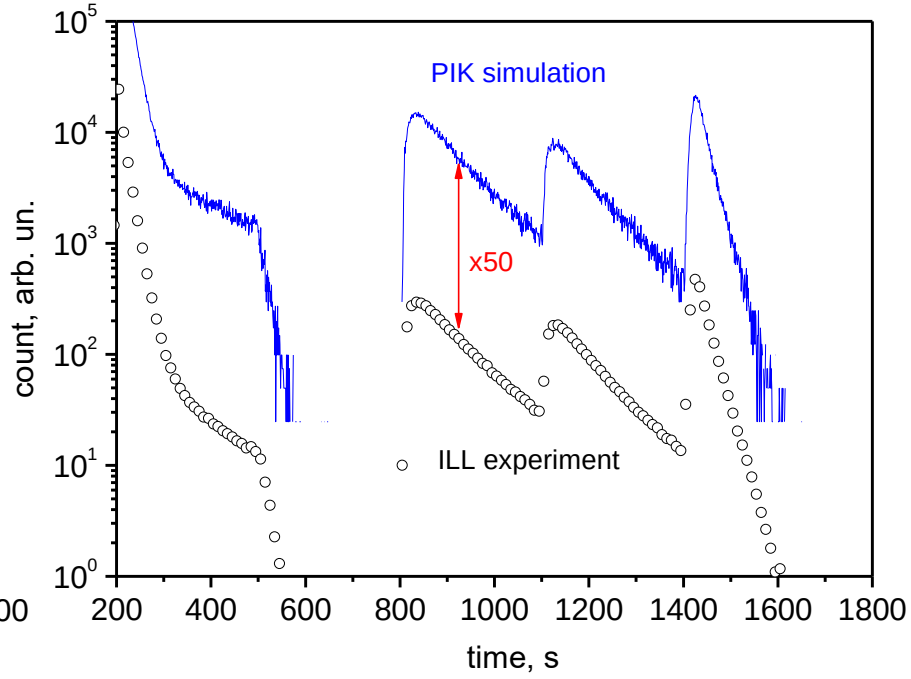
Calculational scheme



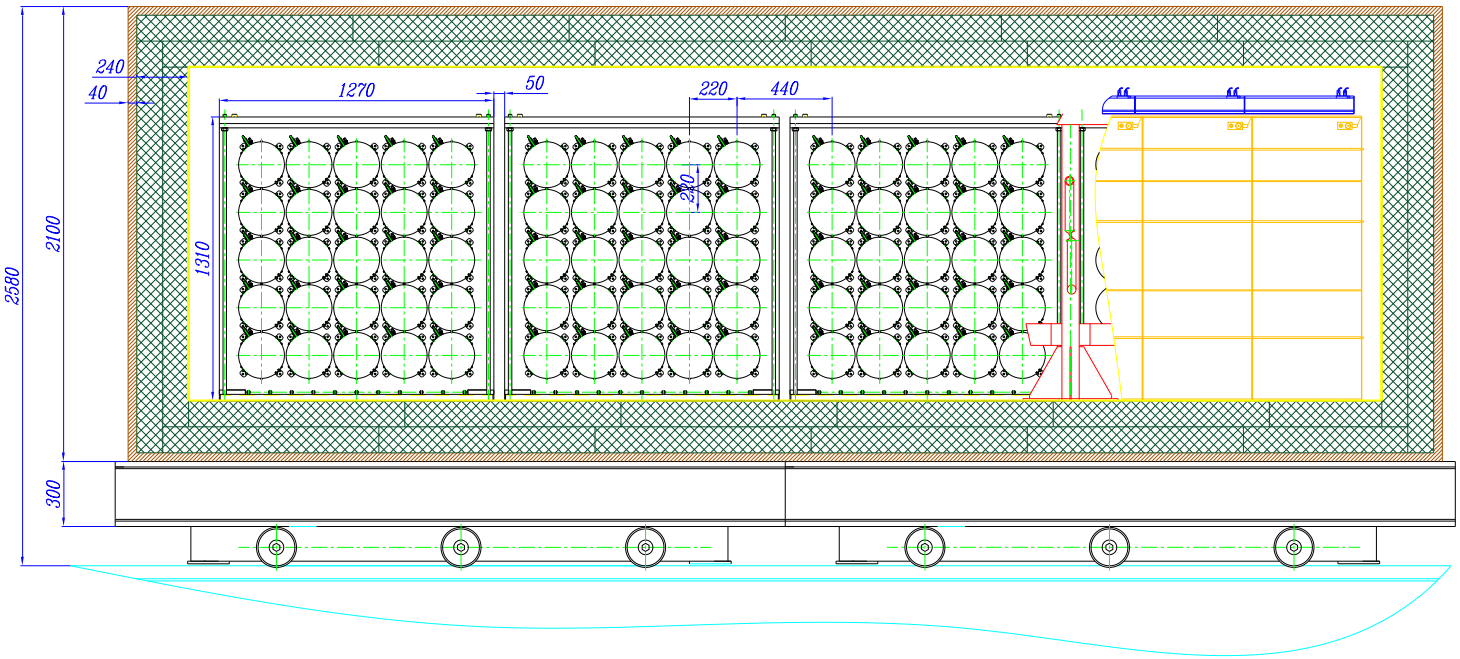


MC simulation

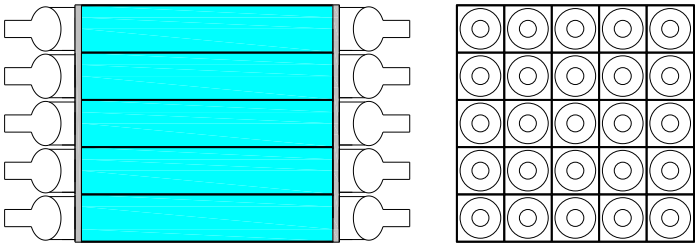


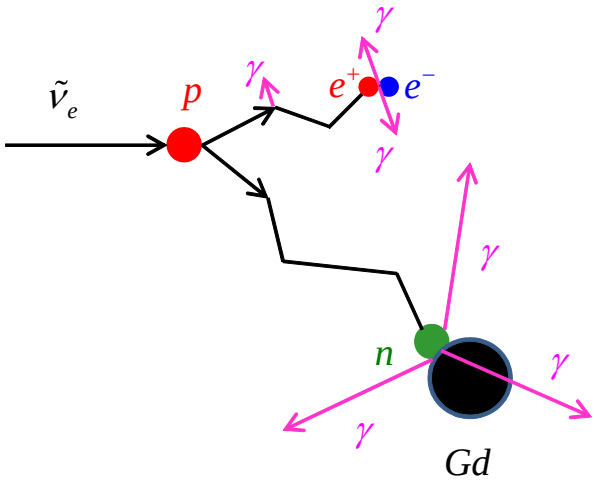


Neutrino-4 experiment to search for sterile neutrino

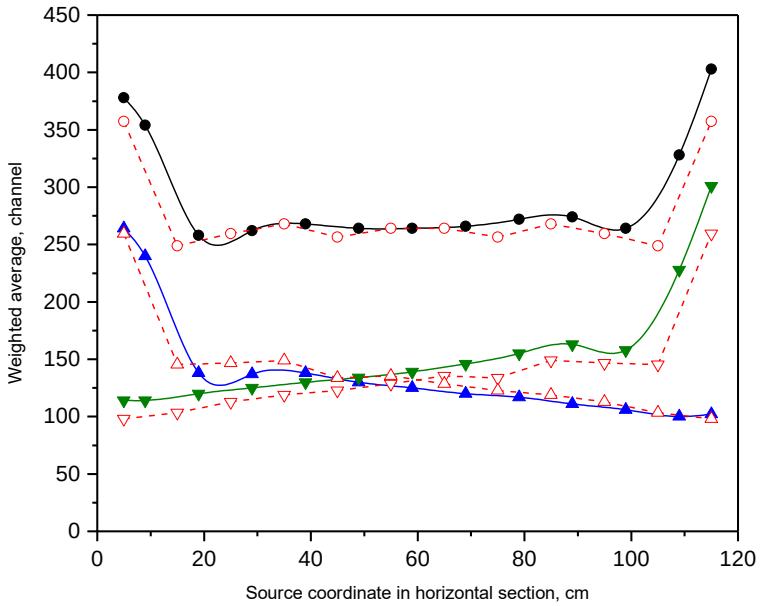


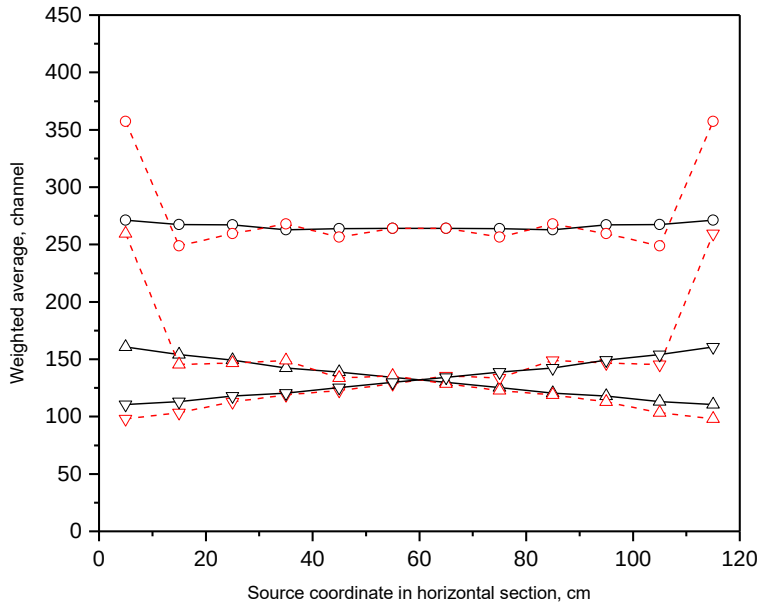
$$P(\tilde{\nu}_e \to \tilde{\nu}_e) = 1 - \sin^2 2\theta_{14}\ \sin^2\left(1.27\frac{\Delta m^2_{14}[eV^2]L[m]}{E_{\tilde{\nu}}[MeV]}\right)$$

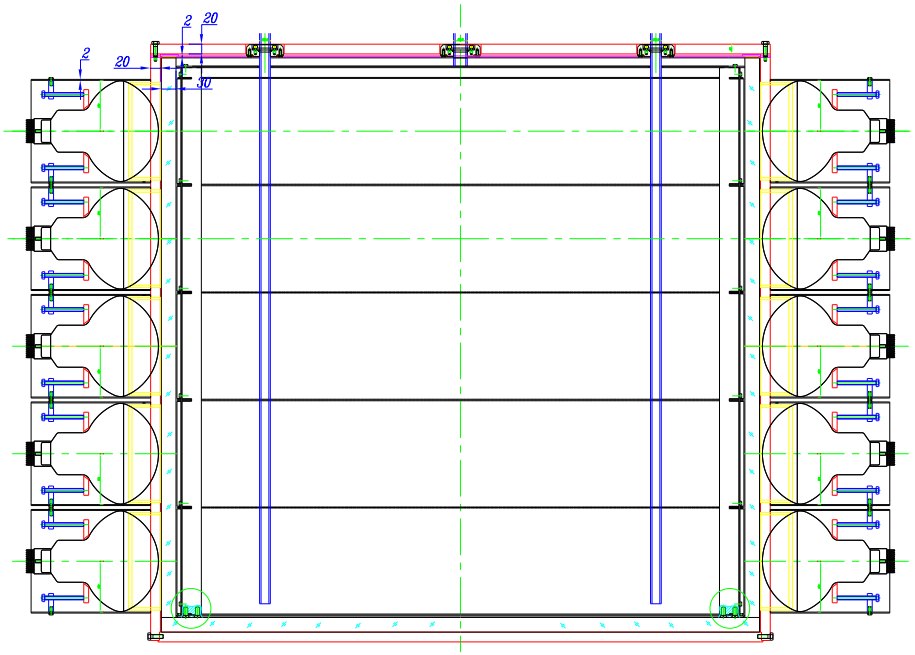


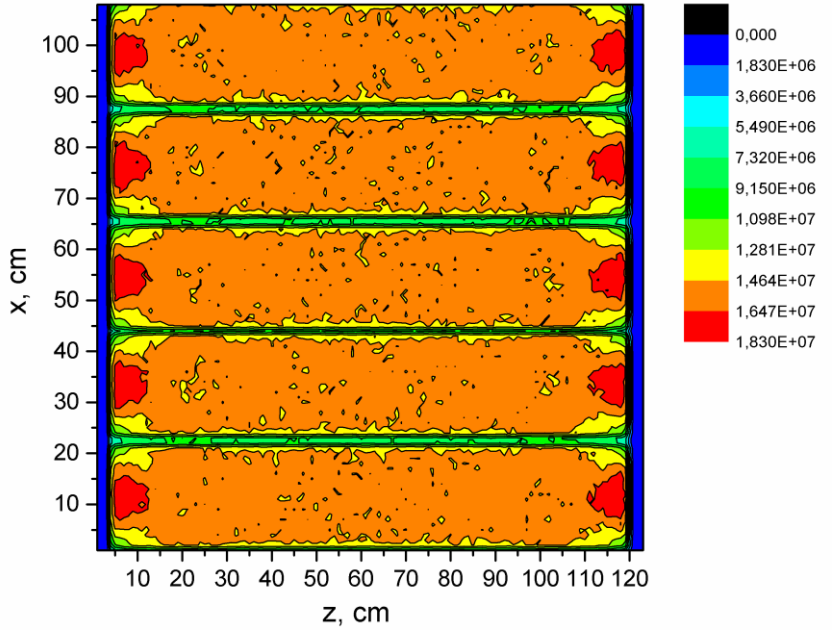


PMT count for different source position

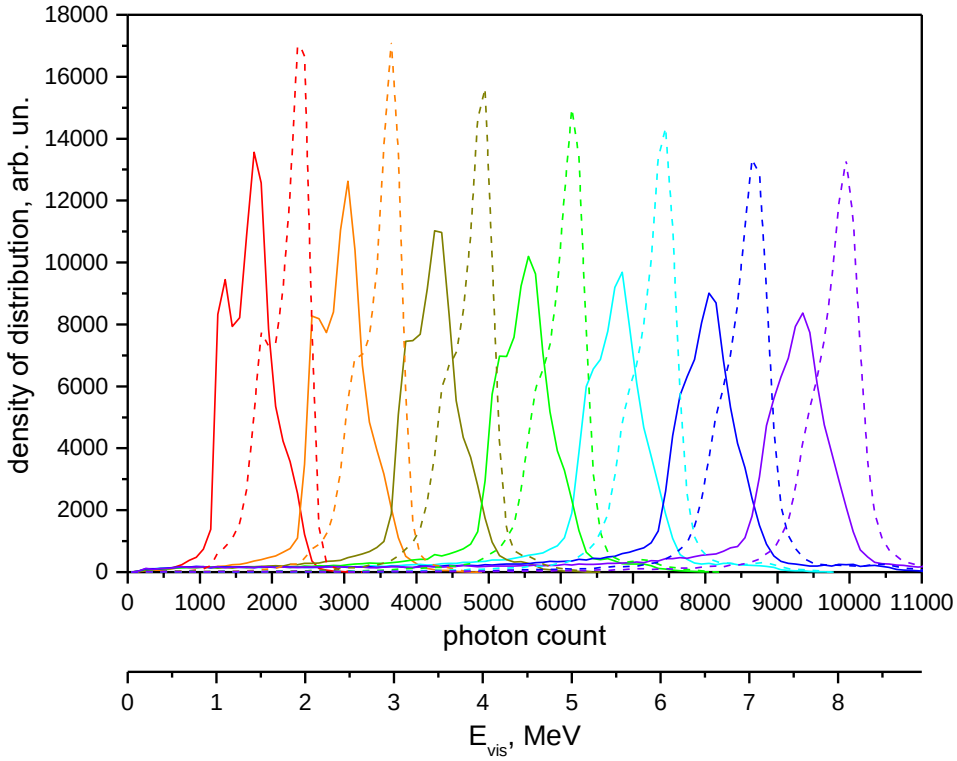


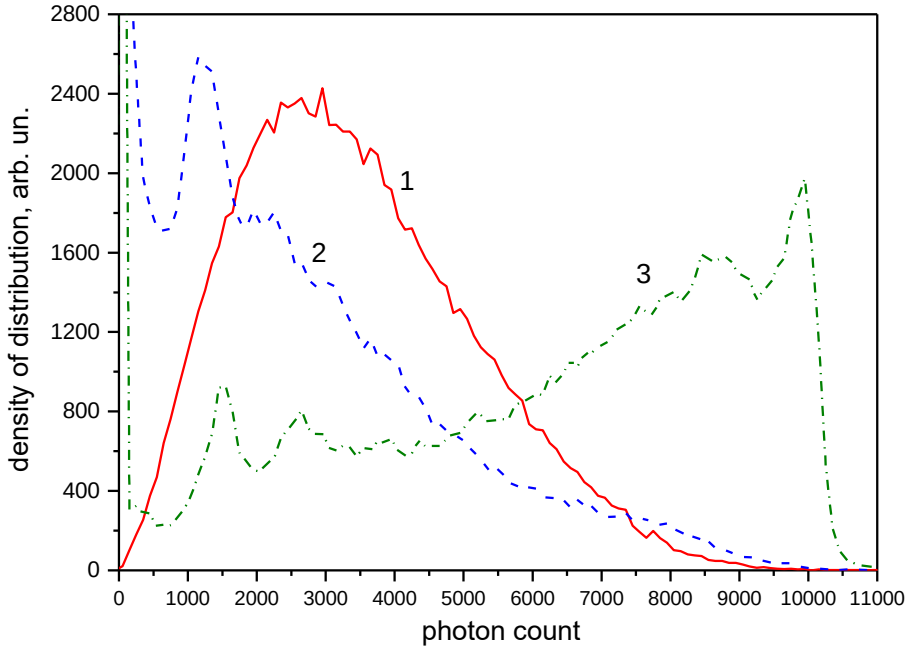




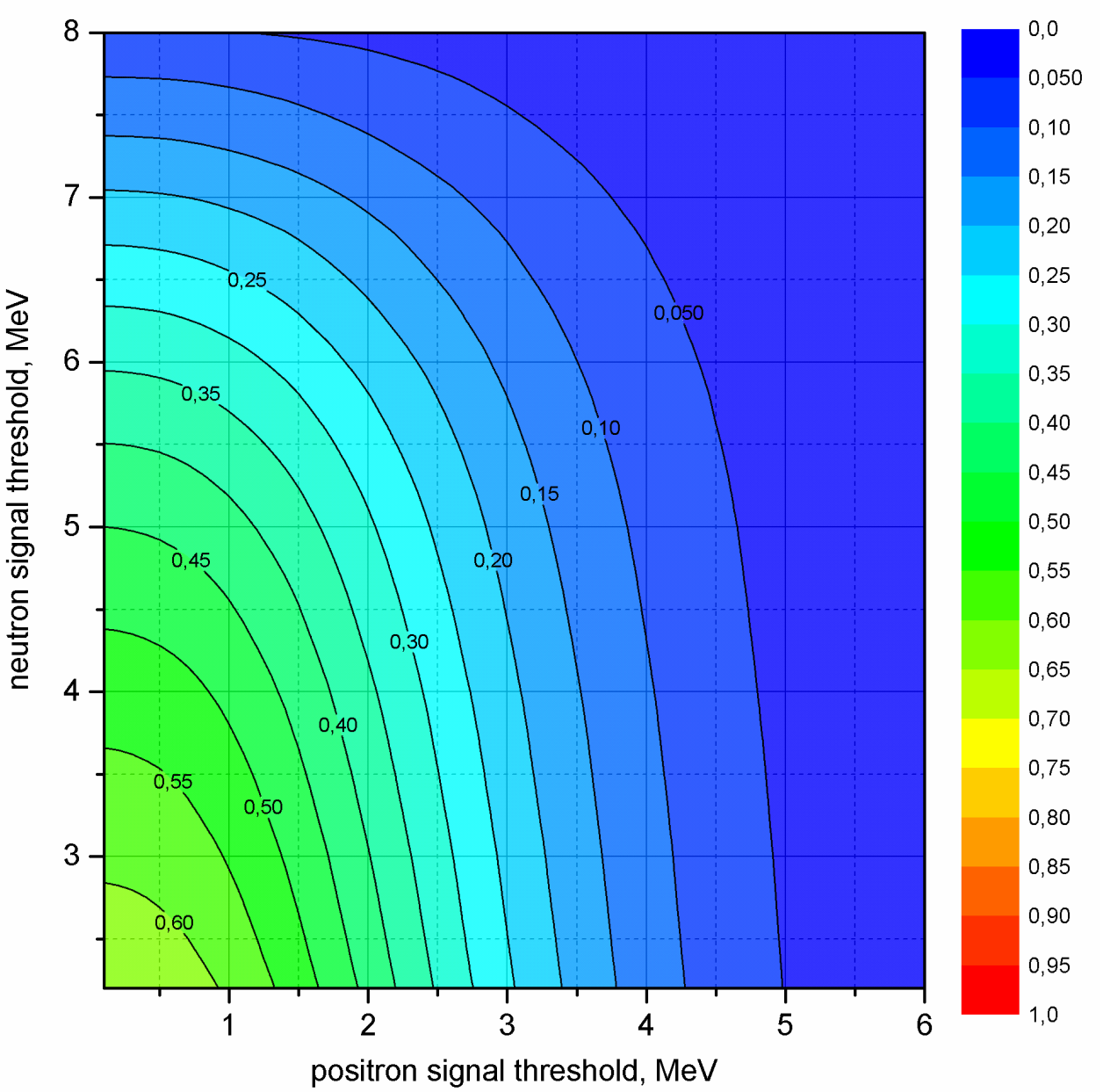


Signals in detector

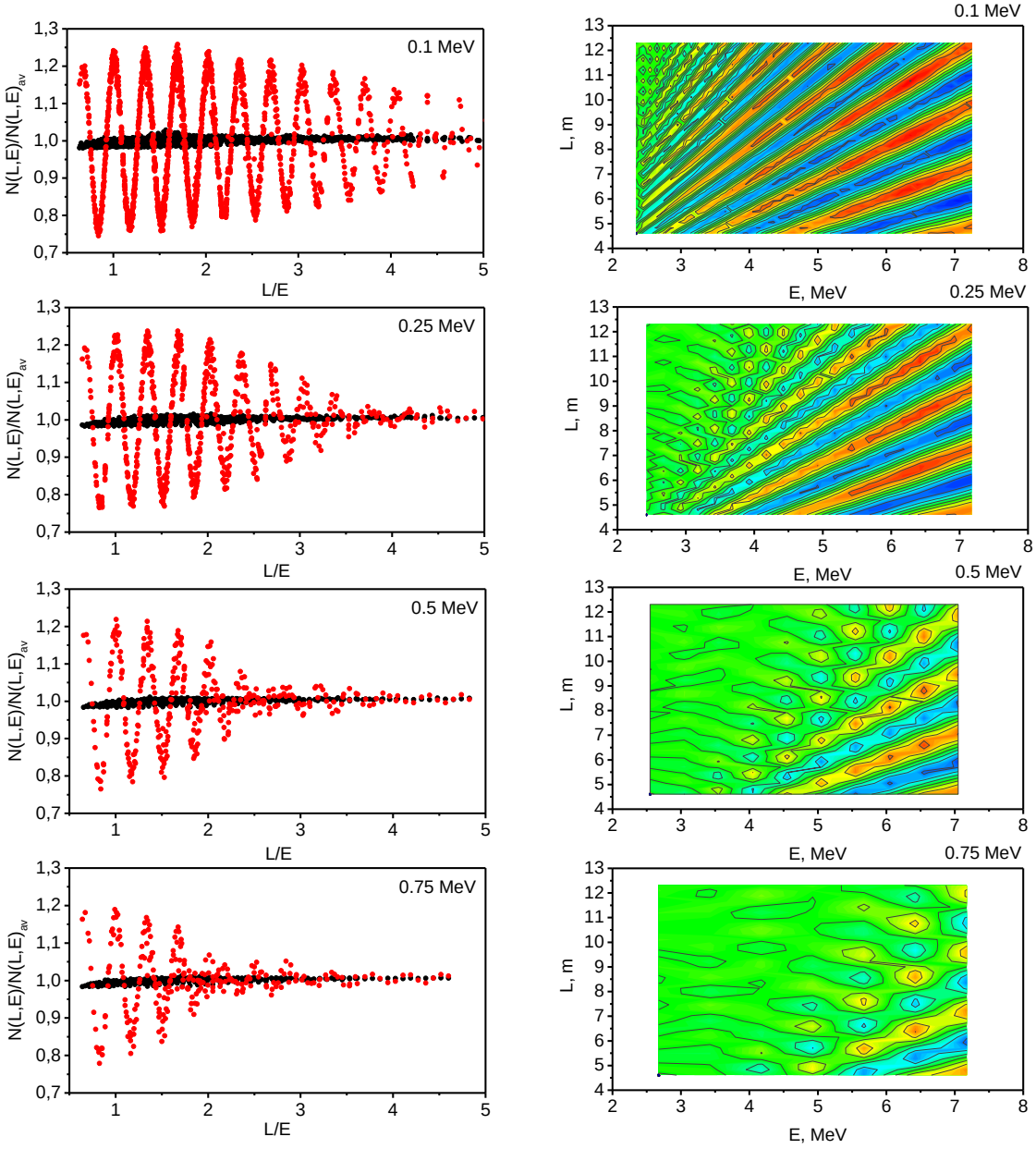




Efficiency of the detector



The expected effect for the different energy resolution from MC calculation



PIK data center

http://top50.supercomputers.ru

Текущий рейтинг (Редакция №37 от 26.09.2022)

№	Название Место установки	Узлов Проц. Ускор.	Архитектура: кол-во узлов: конфигурация узла сеть: вычислительная / сервисная / транспортная	Rmax Rpeak (Тфлоп/с)	Разработчик *Область применения*
24 ▽	«Суперкомпьютер "Константинов"» ПИЯФ, НИЦ "Курчатовский институт", Санкт-Петербург	268 496 н/д	160: CPU: 2x Intel Xeon E5-2680v4, 128 GB RAM 40: CPU: 1x Intel Xeon Phi 7250, 112 GB RAM 30: CPU: 2x Intel Xeon E5-2680v4, 256 GB RAM 20: CPU: 2x Intel Xeon E5-2650v4, 256 GB RAM 16: CPU: 2x Intel Xeon E5-2680v4, 1024 GB RAM 2: CPU: 2x Intel Xeon E5-2680v4, 1540 GB RAM	200.44 362.38	**NP-IT** **Ниагара** **Компьютерс** *Исследования*

Conclusion

1. nEDM

   $\delta d_n \sim 1.5 \cdot 10^{-26}$ e·cm/day at PIK with $\rho_{ucn} \sim 200$ cm^{-3}

   $\delta d_n \sim 1 \cdot 10^{-27}$ e·cm/year

2. Neutron lifetime

   Gain to ILL ~50

   Statistical uncertainty $\rightarrow$ 0.1 s

3. Neutrino-4

   MC simulation provided development and predictions for the result