Experiment on search for neutron-antineutron oscillations using a projected UCN source at the WWR-M reactor

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Baryon Asymmetry

Baryon Asymmetry in our Universe

Electroweak SM expectation:

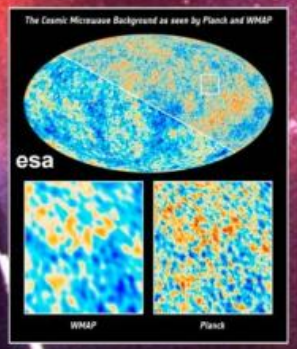
$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-18}$$

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*

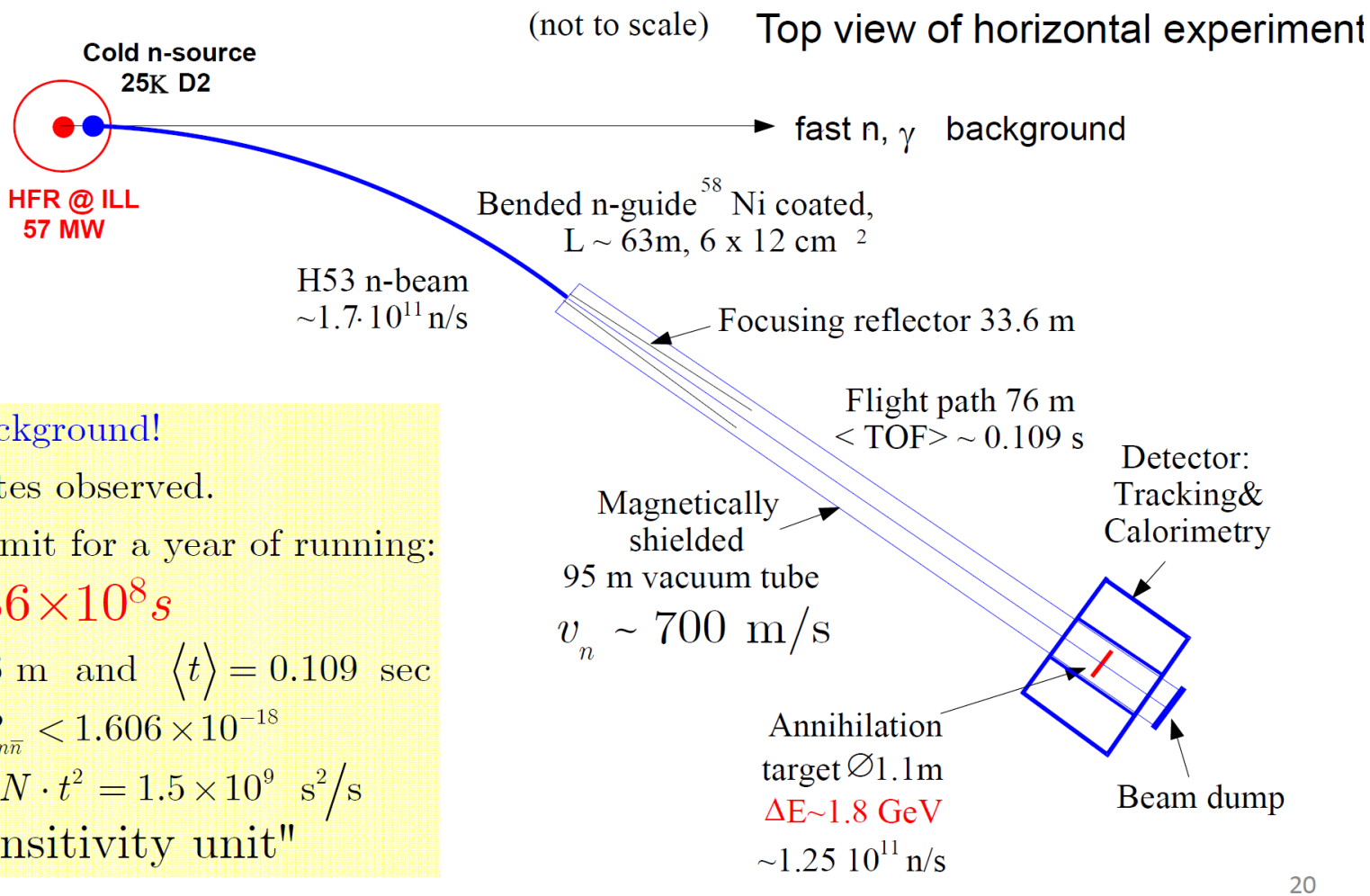
JETP Lett. 5, 24 (1967)

* e.g. WMAP, COBE, Planck

ILL beam experiment

At ILL/Grenoble reactor in 89-91 by Heidelberg-ILL-Padova-Pavia Collaboration

M. Baldo-Ceolin et al., Z. Phys., C63 (1994) 409



No GeV background!

No candidates observed.

Measured limit for a year of running:

$\tau_{n\bar{n}} > 0.86 \times 10^8 s$

with L ~ 76 m and $\langle t \rangle = 0.109$ sec

measured $P_{n\bar{n}} < 1.606 \times 10^{-18}$

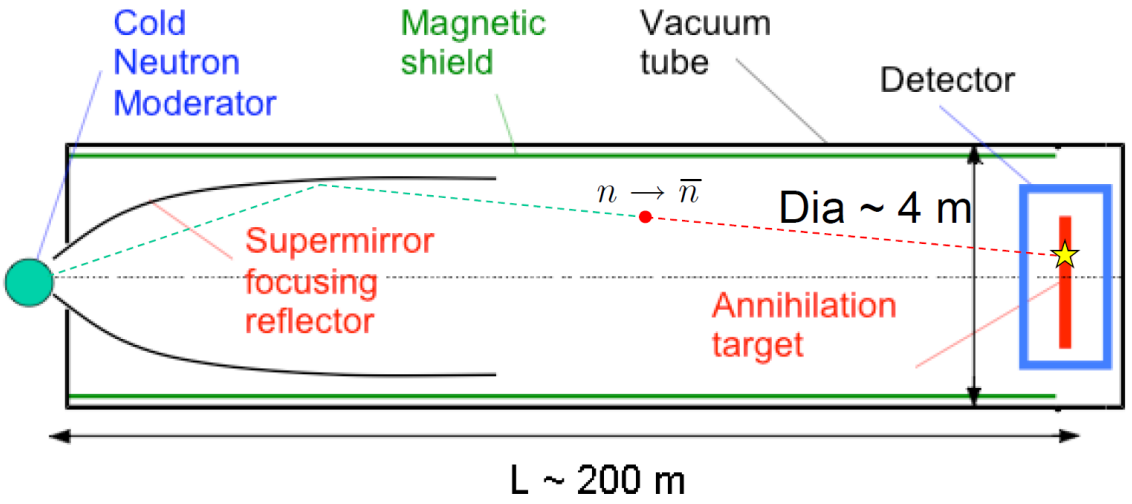
sensitivity: $N \cdot t^2 = 1.5 \times 10^9$ s^2/s

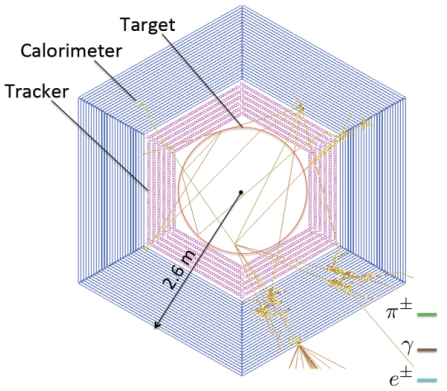
≐ "ILL sensitivity unit"

20

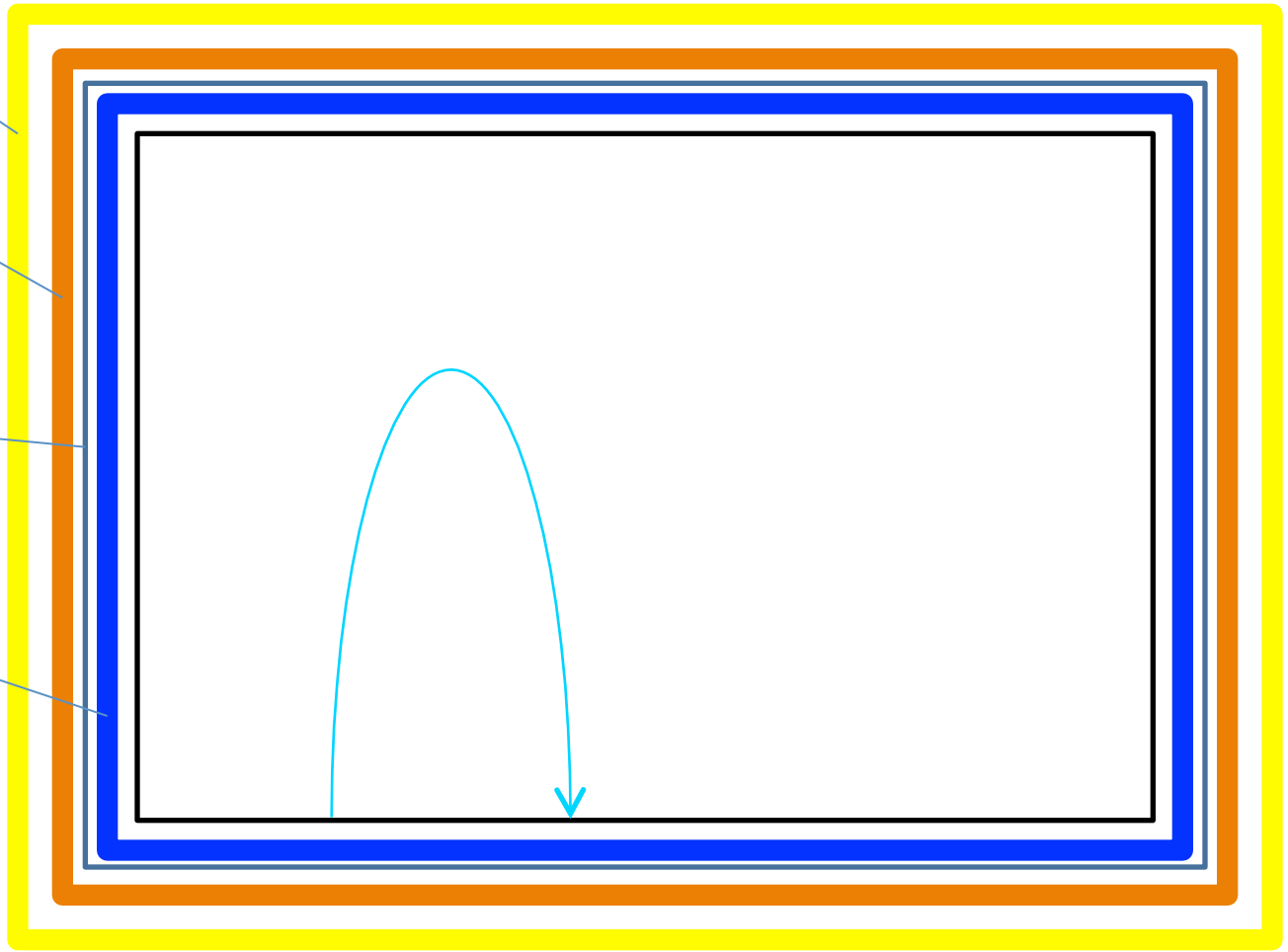
ESS beam experiment

Scheme of Horizontal N-Nbar experiment for ESS Neutron Source





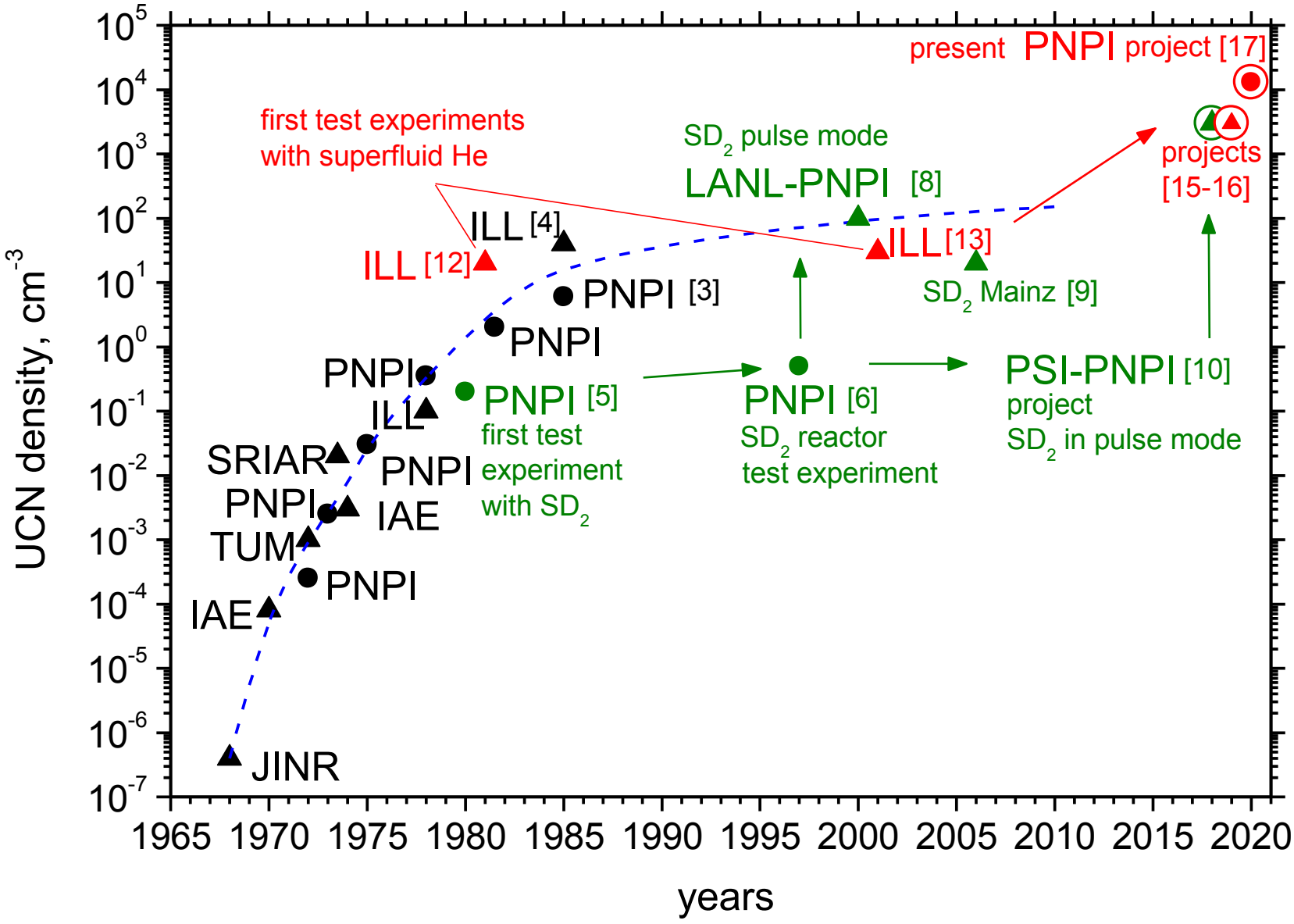
NNbar via UCN



$N \cdot t^2$ – discovery potential

Storage trap: height 2.5 m, $v_{boundary}$ = 6.8 m/s, diffusion 90 %, abs. in walls $3 \cdot 10^{-5}$

Progress of UCN sources



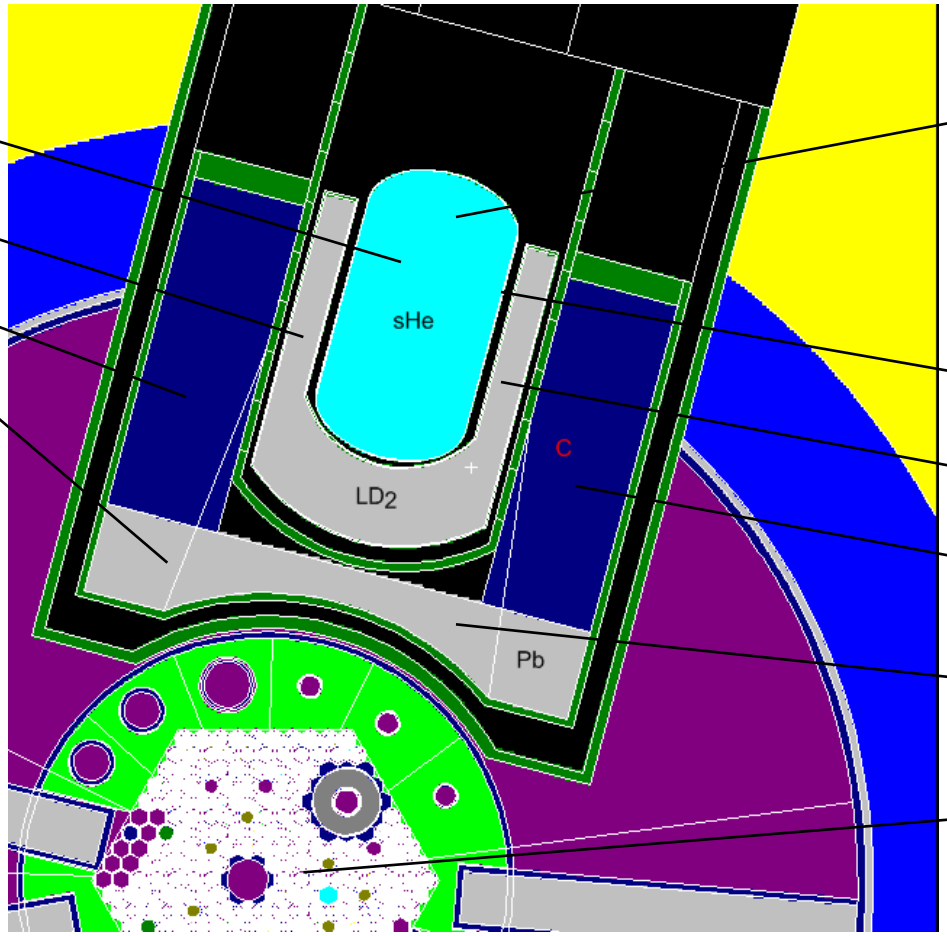
MCNP neutron flux calculation results and heat generation in thermal column of WWR-M reactor at 15 MW

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

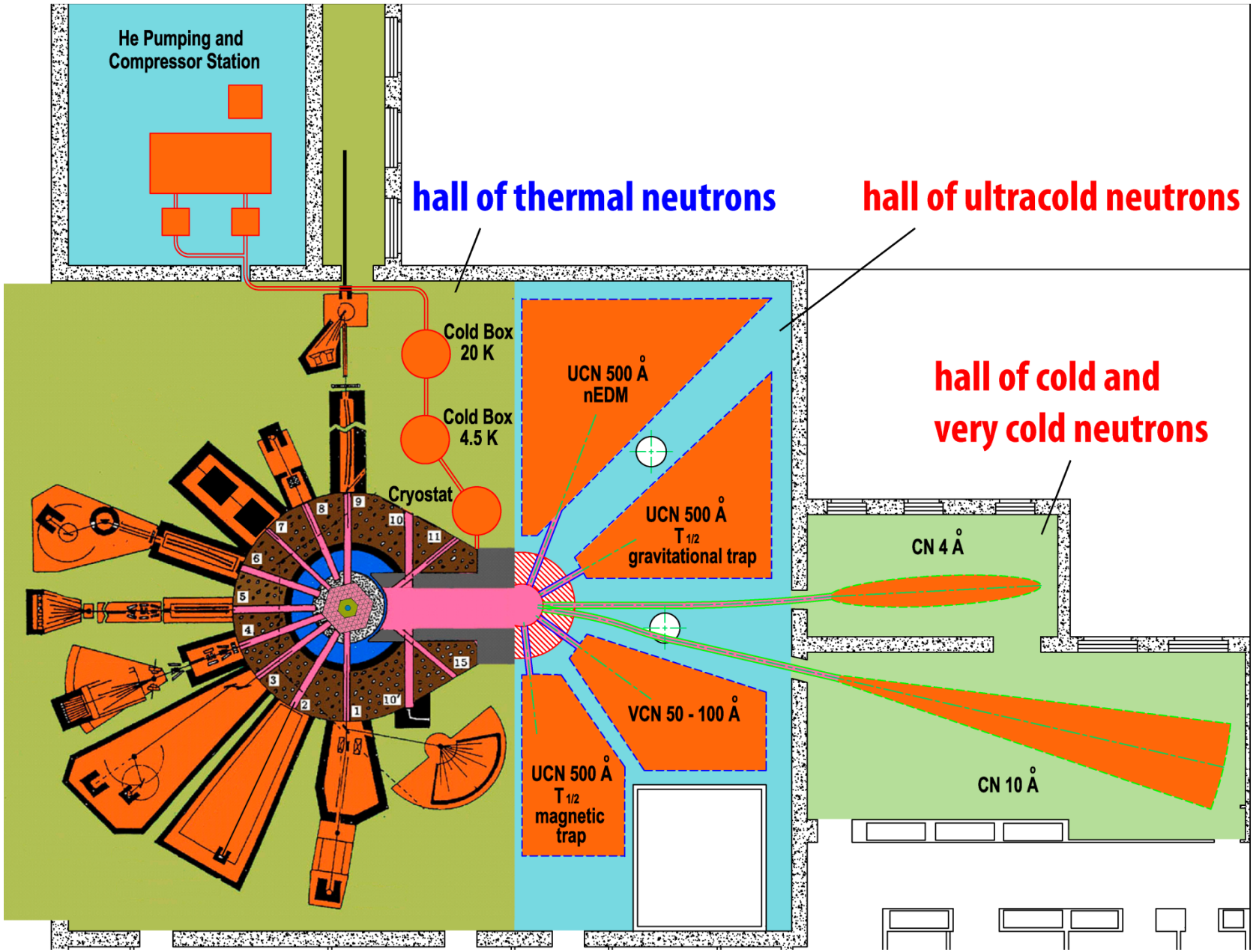
Pb, Q_{Pb}=15 кW

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

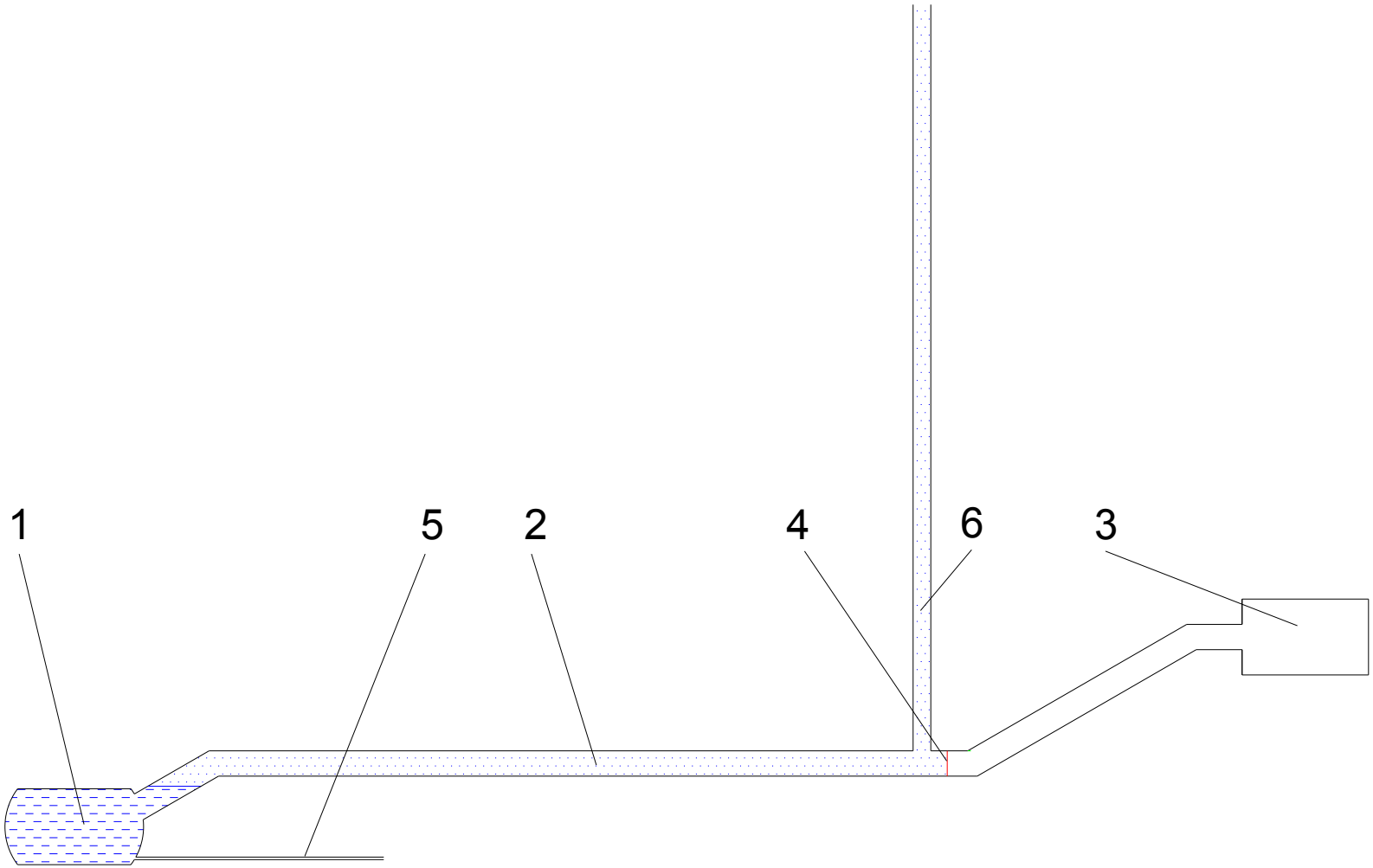
Q=15 MW

7

Project of UCN source at reactor WWR-M (PNPI, Gatchina)

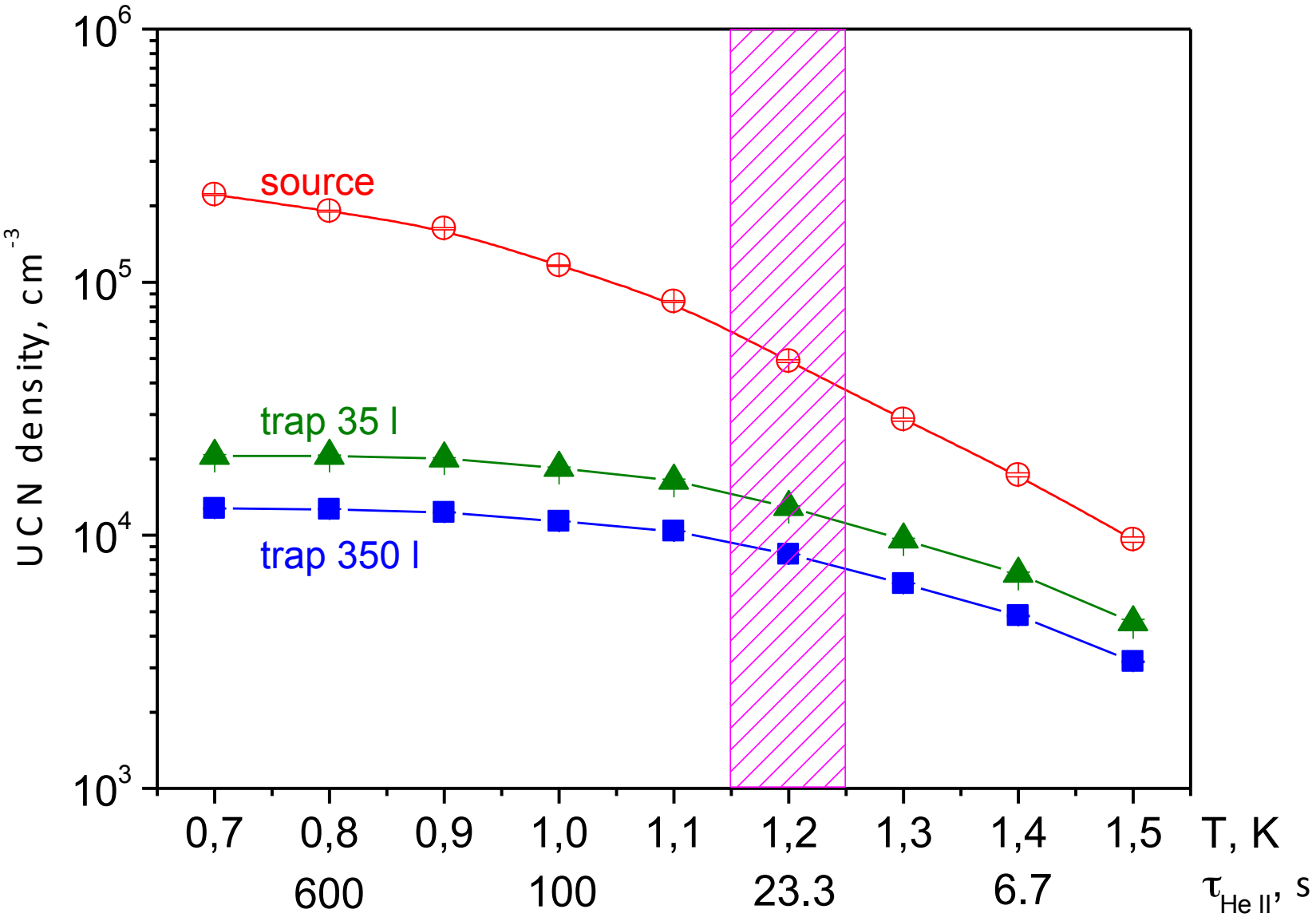


MC model of the source



(*1*) source chamber; (*2*) neutron guide; (*3*) UCN trap; (*4*) membrane in front of the inlet to the UCN trap;(*5*) pipe for filling the chamber; (*6*) pipeline for evacuation of the chamber (UCN gravitational shutter)

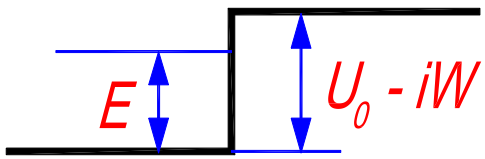
UCN density



Production of the source 10^8 UCN/s.

What is the probability for UCÑ to be reflected?

$$R = \left| \frac{1 - \sqrt{1 - \frac{U_0}{E_\perp}(1 - i\eta)}}{1 + \sqrt{1 - \frac{U_0}{E_\perp}(1 - i\eta)}} \right|^2$$

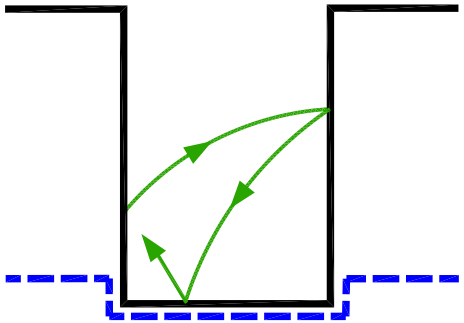


$$U = U_0 - iW \qquad \eta = \frac{W}{U_0}$$

We can consider two cases:

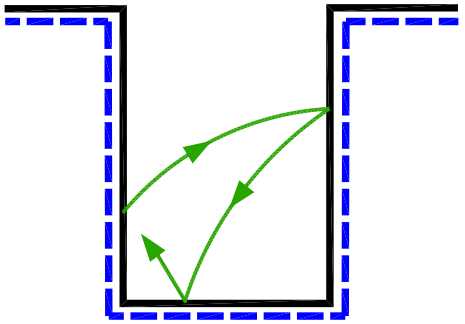
1. $R_0 = 0$

   (pessimistic case)



2. $R_0 = R_0(\eta = 0.2) \approx 0.8$

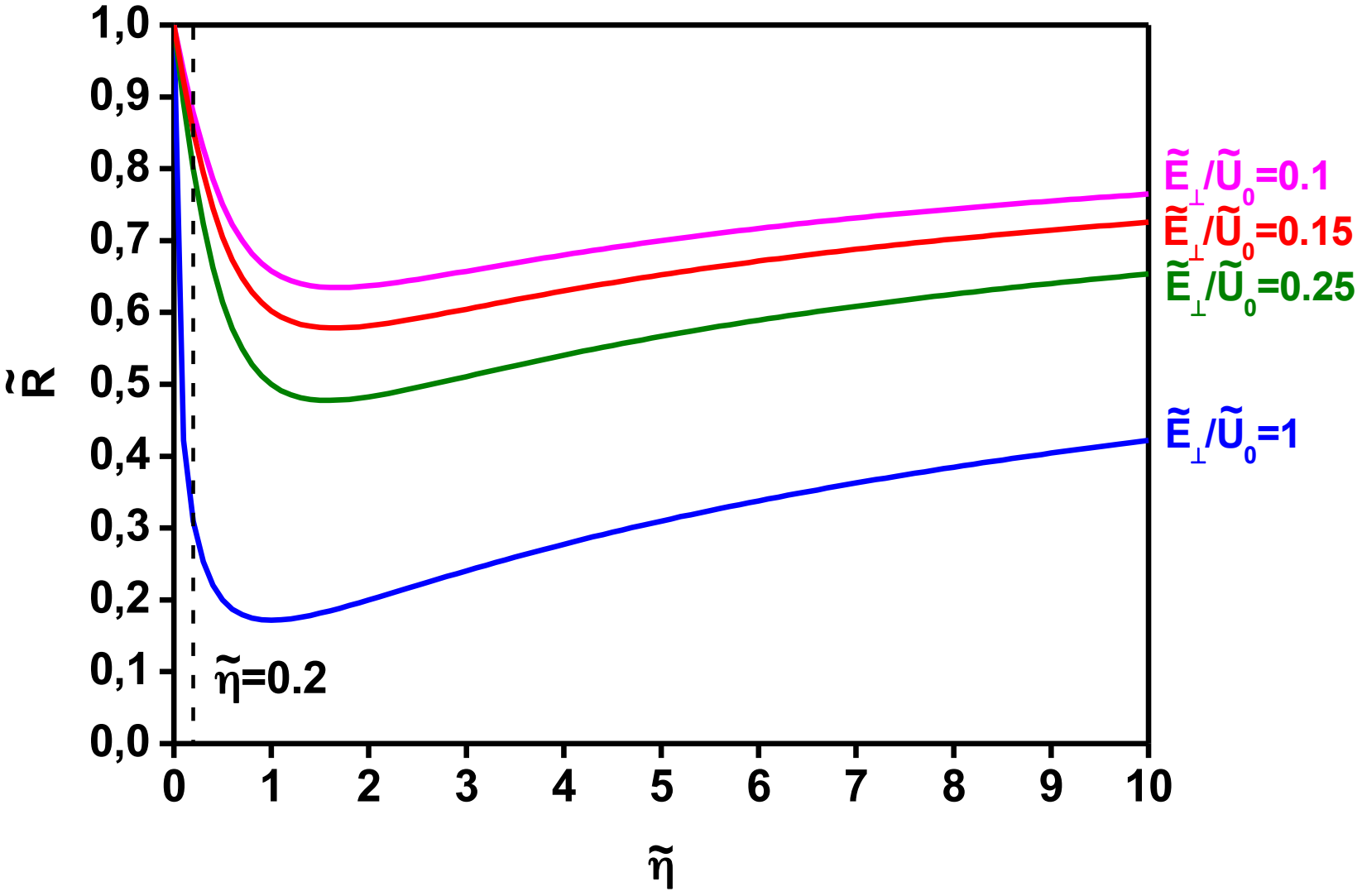
   (optimistic case)



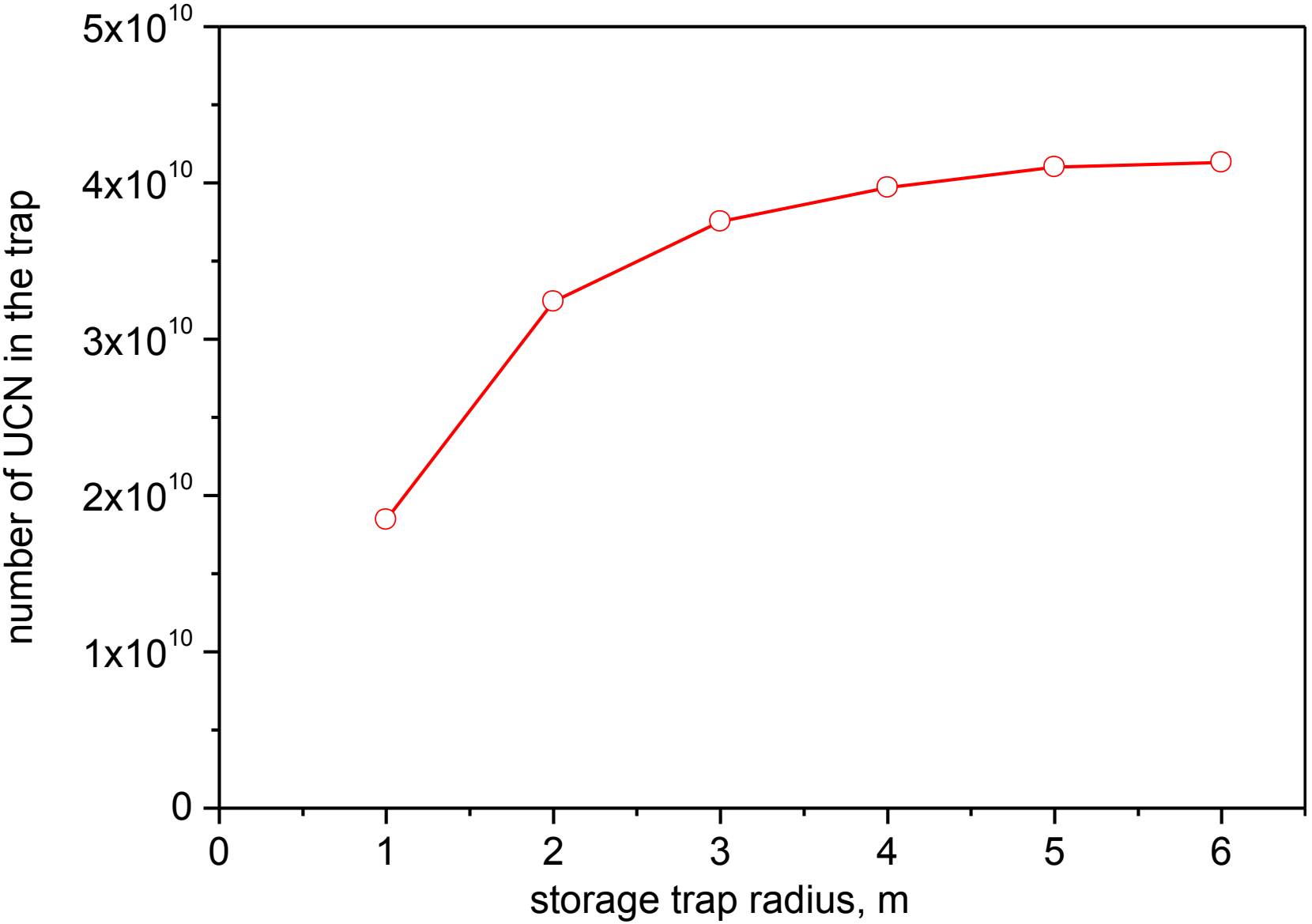
$U_0 - iW$ for n ——

$U_0 - iW$ for n – – –

Reflection coefficient for UCÑ

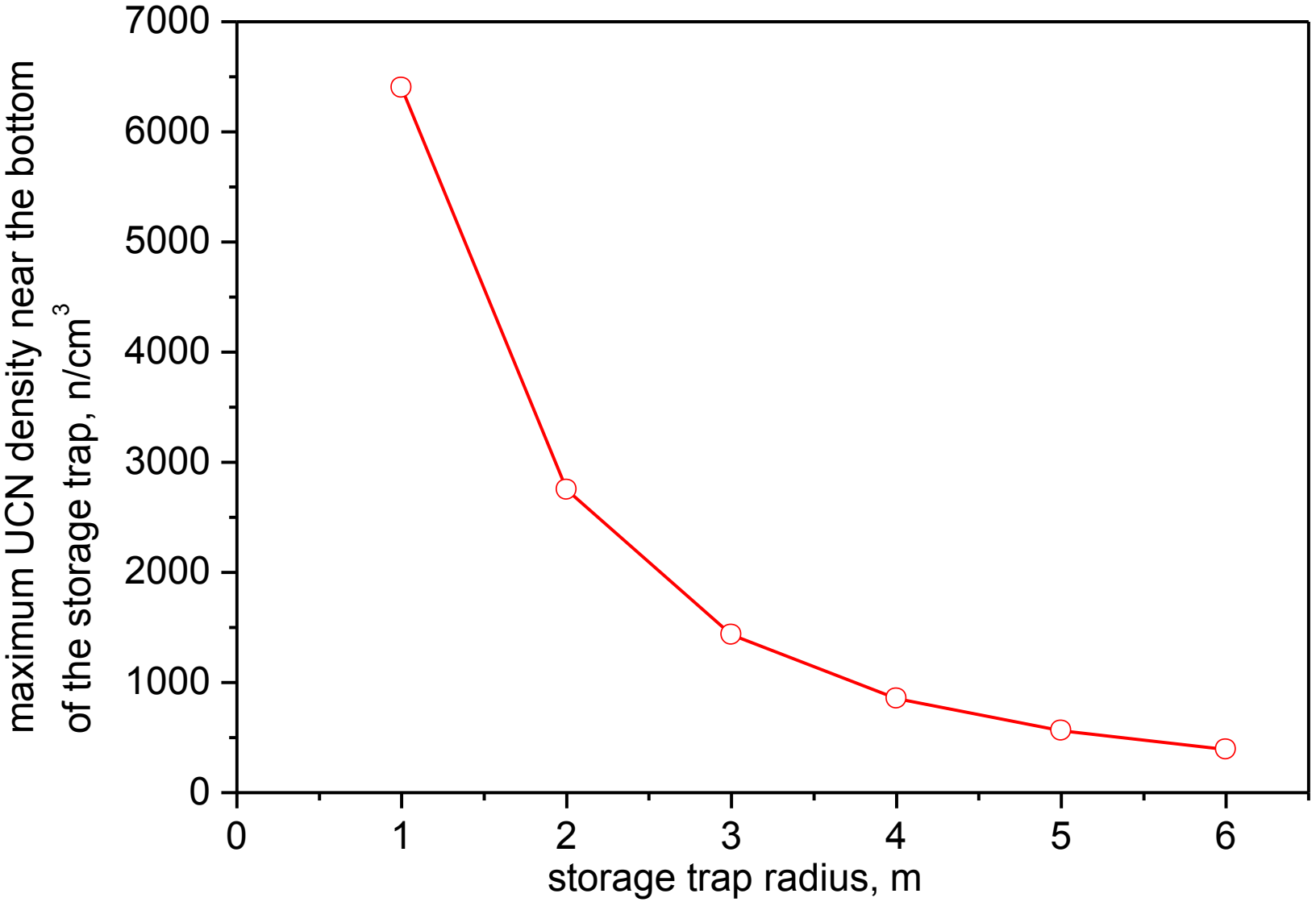


UCN number in the trap for different storage trap radius



Storage trap: height 2.5 m, $v_{boundary}$ = 6.8 m/s, diffusion 90 %, abs. in walls $3 \cdot 10^{-5}$

UCN density for different storage trap radius



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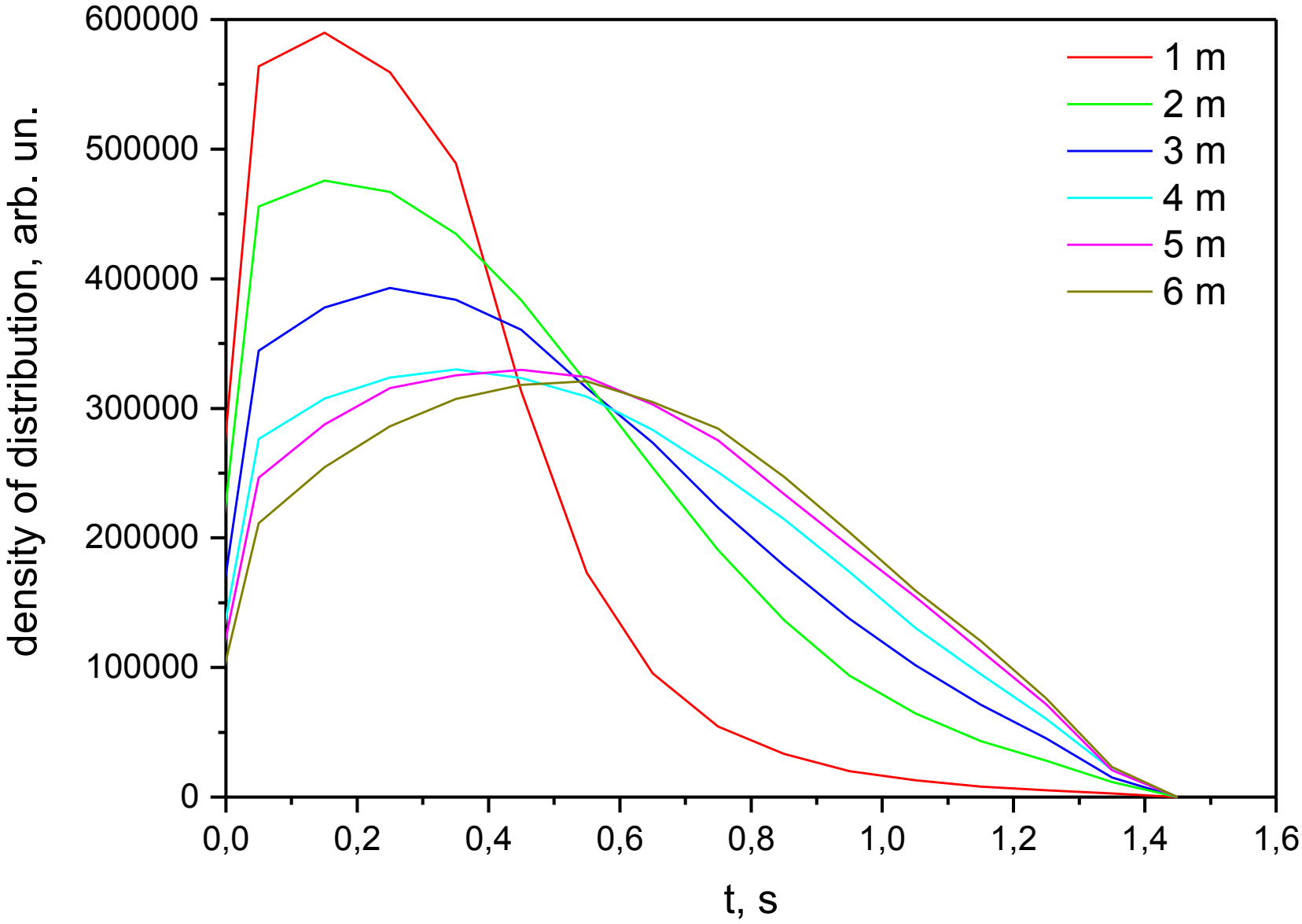
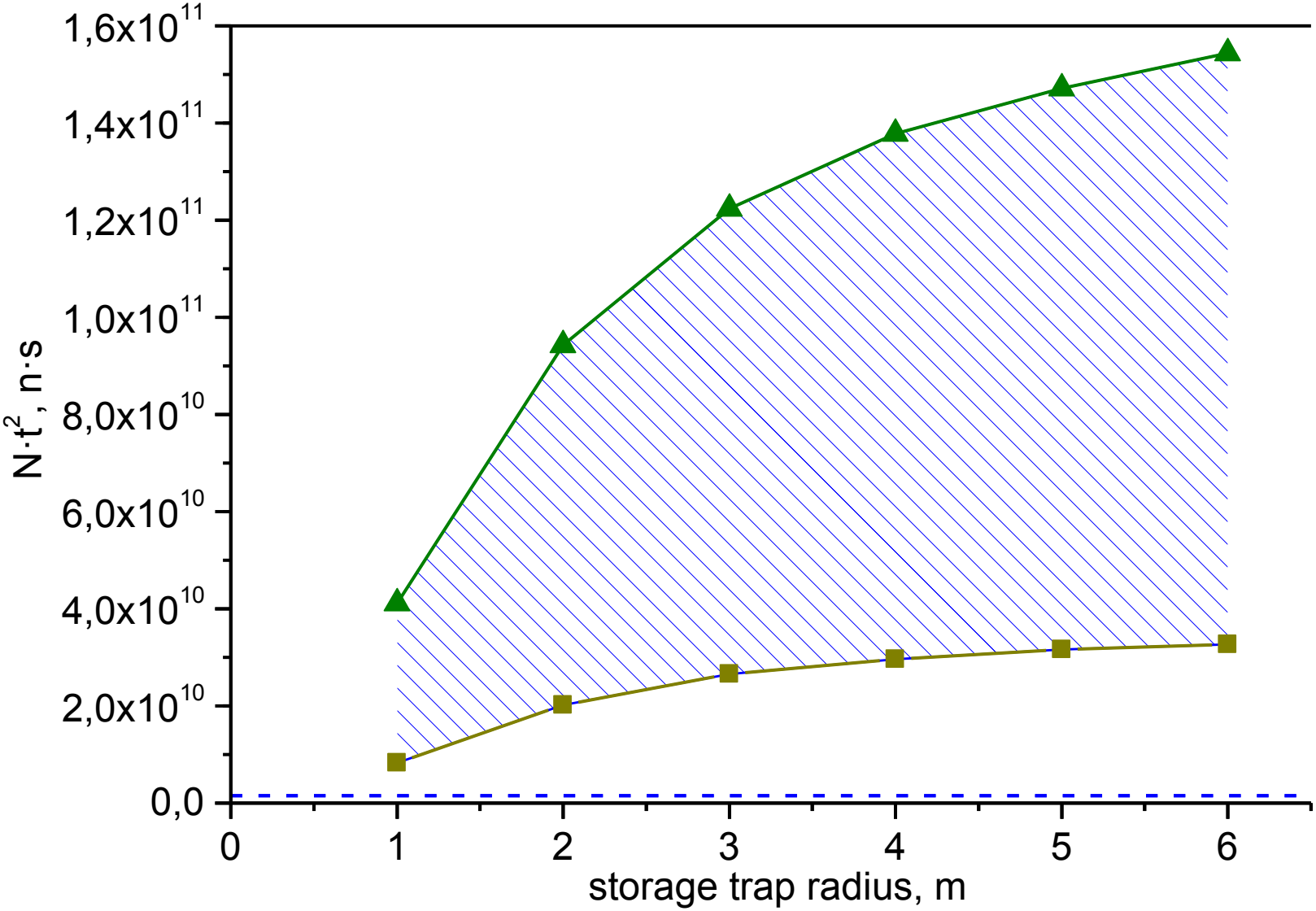
UCN time of flight for different storage trap radius



Storage trap: height 2.5 m, $v_{boundary}$ = 6.8 m/s, diffusion 90 %, abs. in walls $3 \cdot 10^{-5}$

$N \cdot t^2$ for different storage trap radius



Storage trap: height 2.5 m, $v_{boundary}$ = 6.8 m/s, diffusion 90 %, abs. in walls $3 \cdot 10^{-5}$

Oscillation period

$$\tau_{n\bar{n}} = \sqrt{\frac{(N \cdot t^2) \cdot T \cdot \varepsilon}{N_0}}$$

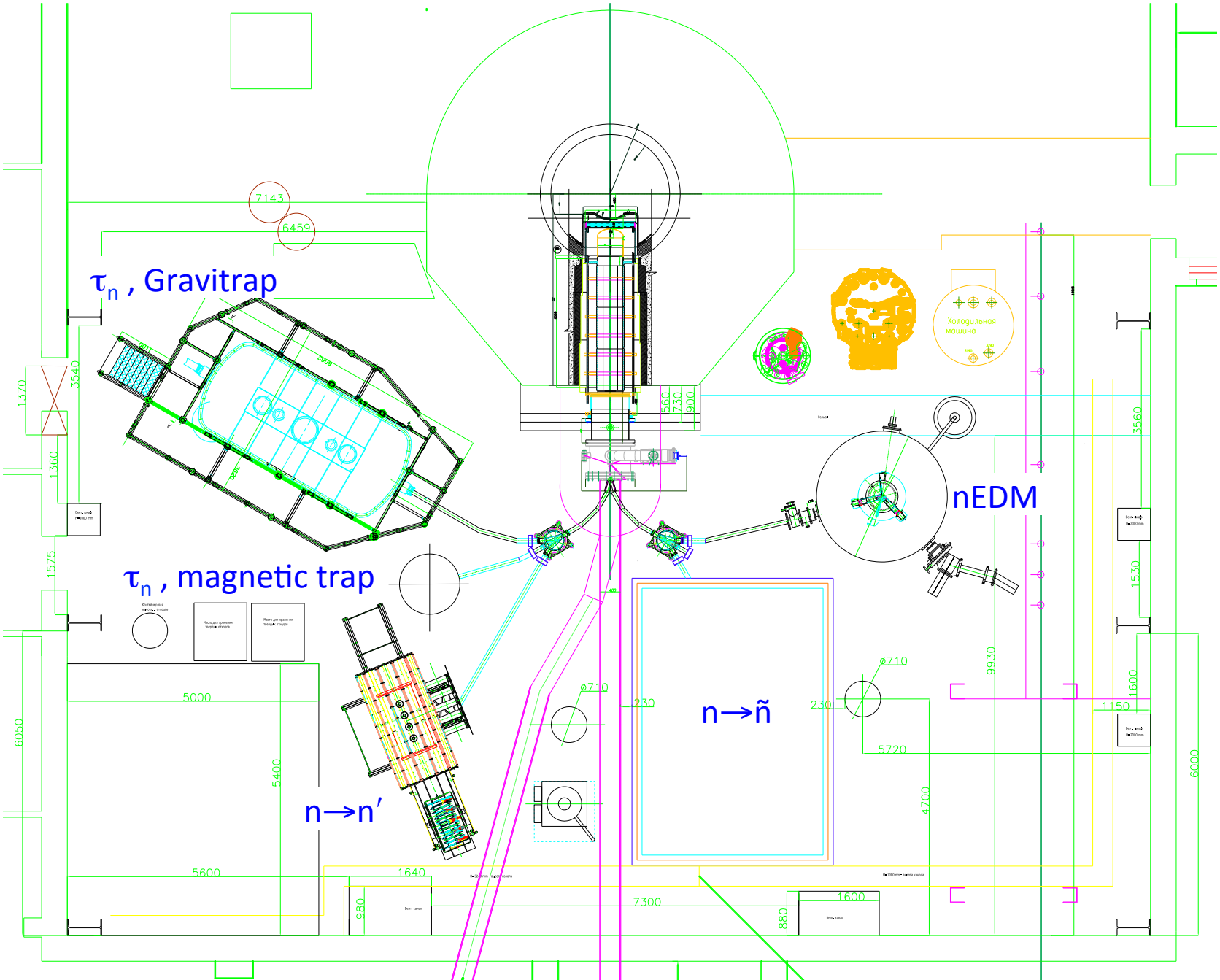
$$T \sim 3 \; years$$

$$\varepsilon = 0.9$$

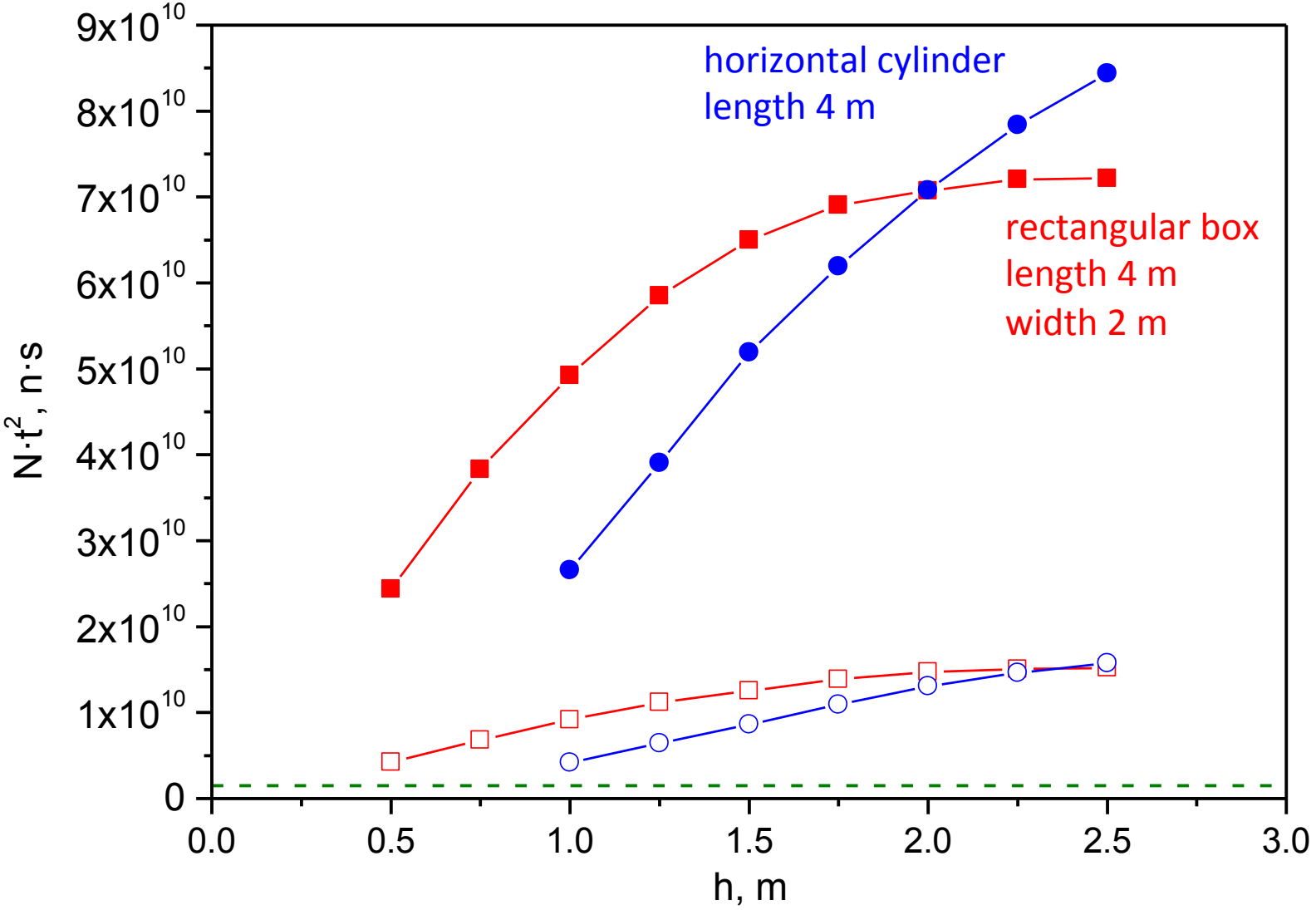
$$N_0 = 0 \; (\leq 2.3 \; \textbf{at 90\% CL})$$

$$\tau_{n\bar{n}} \geq (1 \div 2) \cdot 10^9 \; \textbf{s (90\% CL)}$$

UCN facilities at reactor WWR-M (preliminary)

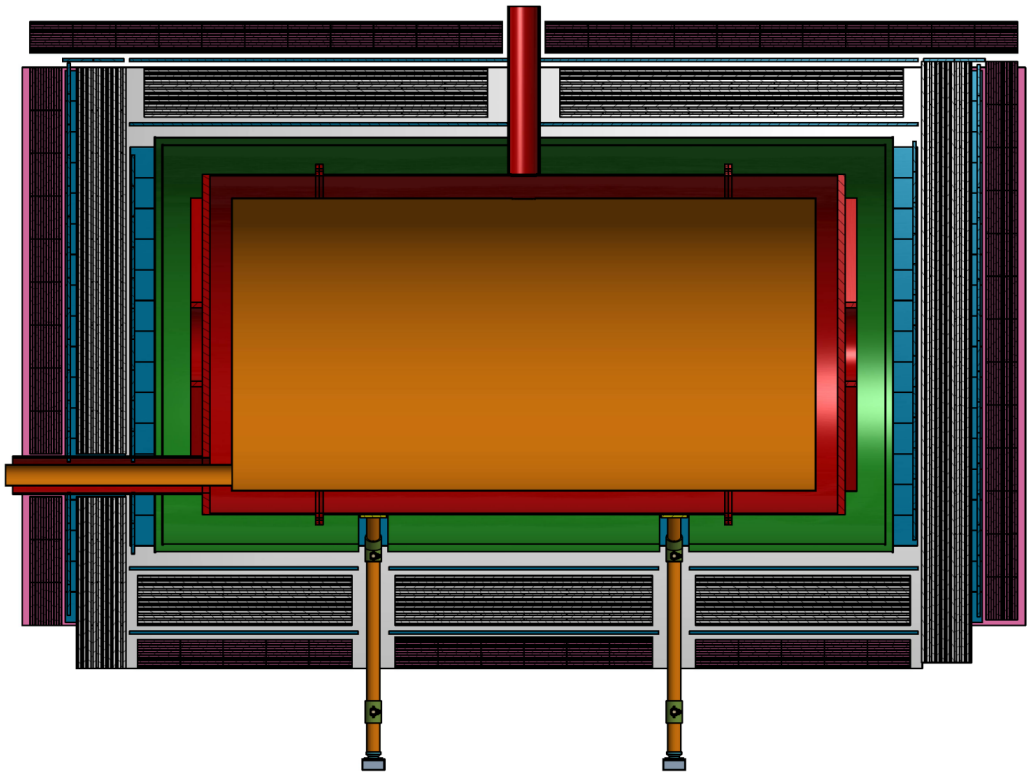


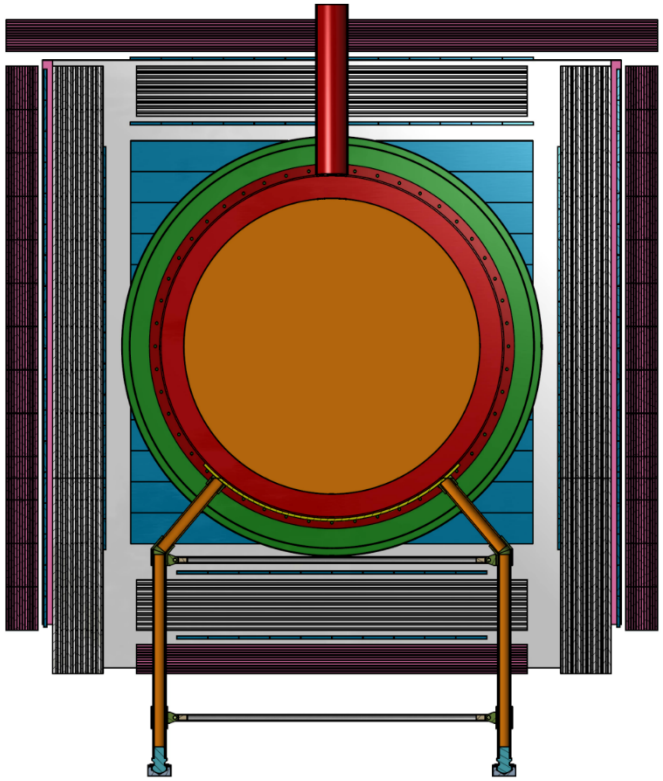
$N \cdot t^2$ for different storage trap height



Storage trap: $v_{boundary}$ = 6.8 m/s, diffusion 90 %, abs. in walls $3 \cdot 10^{-5}$

Design of the setup





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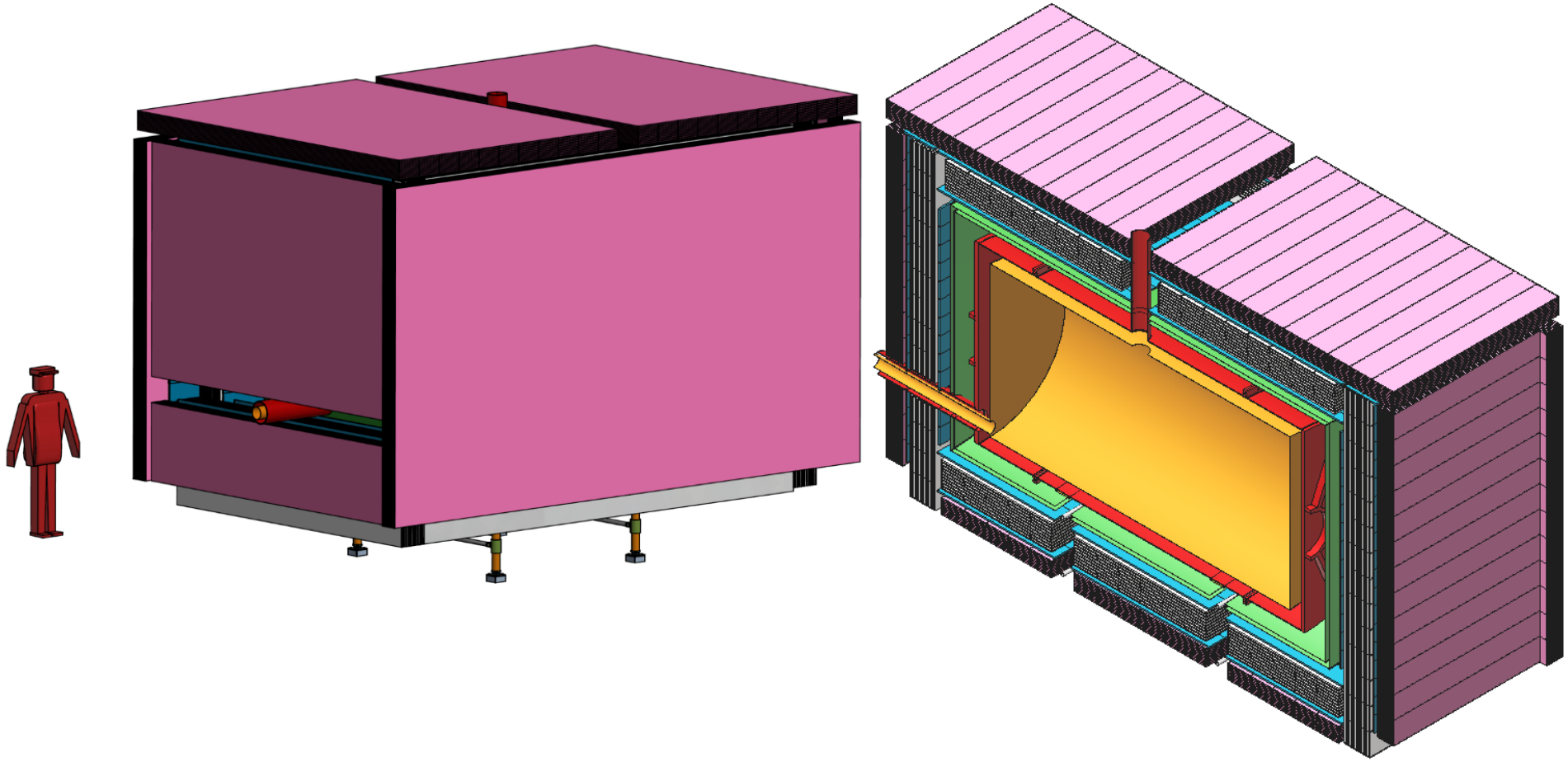

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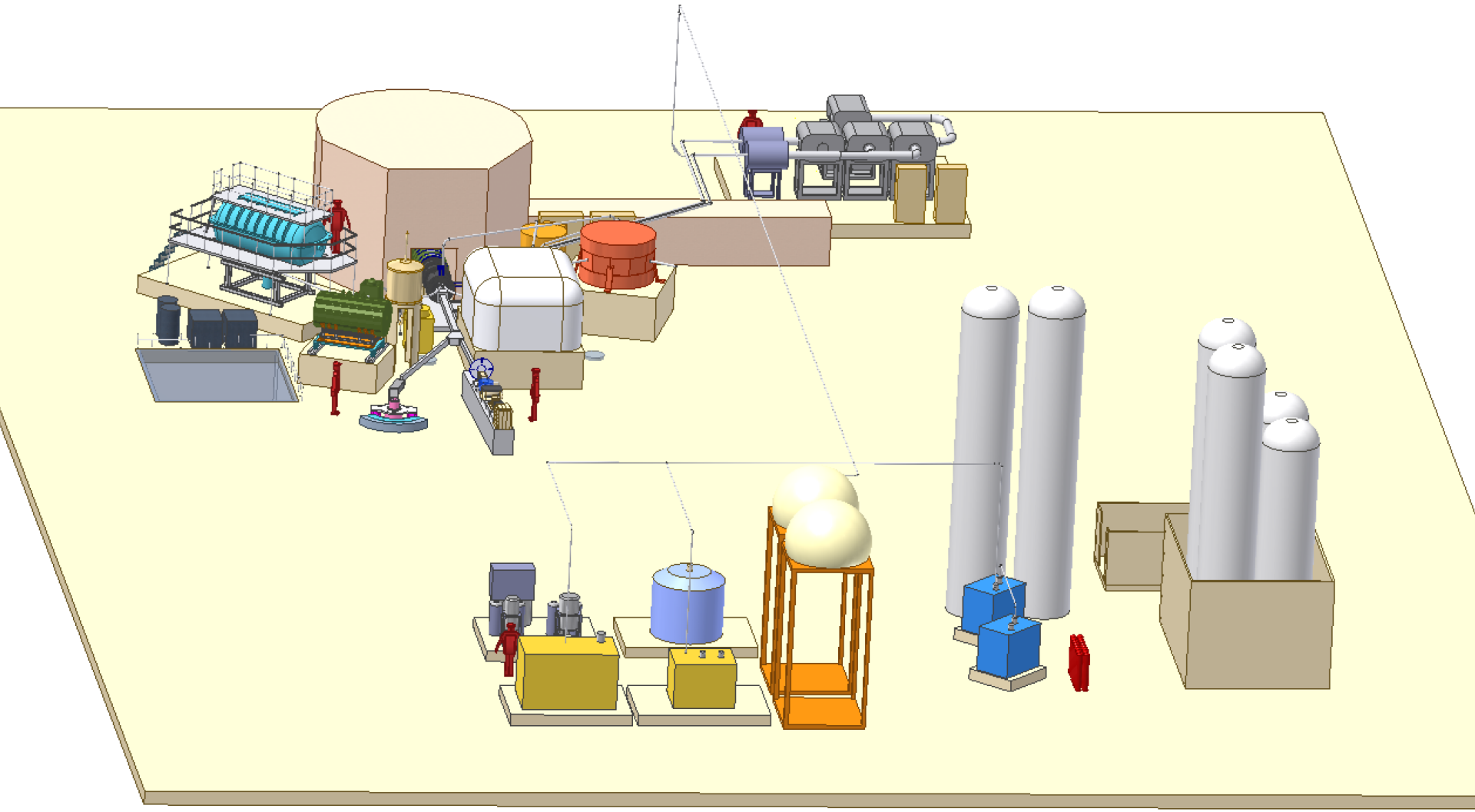

Conclusion

1. Designed storage trap for NNbar oscillation experiment at reactor WWR-M: horizontal cylinder with diameter 2 m, length 4 m.

2. Increase of the experiment sensitivity is about 10 ÷ 40 times to ILL level.

3. Oscillation period for 3 years:

$\tau_{n\bar{n}} \geq (0.7 \div 1.4) \cdot 10^9$ **s (90% CL)**