Status of the νGeN experiment

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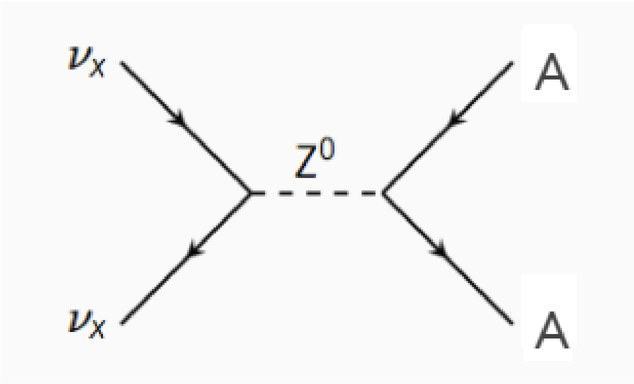
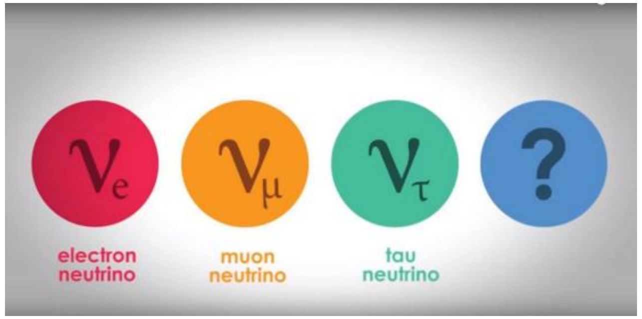
JINR

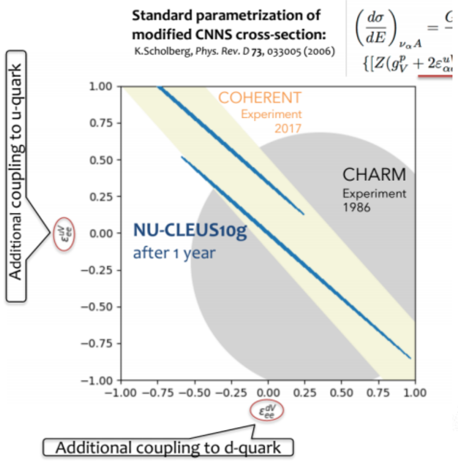
νGeN aims:

νGeN experiment is aimed to study neutrino scattering using antineutrinos from the reactor core of Kalinin Nuclear Power Plant (KNPP) at Udomlya, Russia. Main searches:

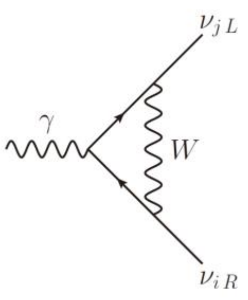
- Coherent elastic neutrino-nucleus scattering (CEvNS).
- Non-standard neutrino interactions.
- Magnetic moment of neutrino.
- Nuclear physics, sterile neutrino.
- Other rare and exotics processes.
- Applied usage: reactor monitoring.



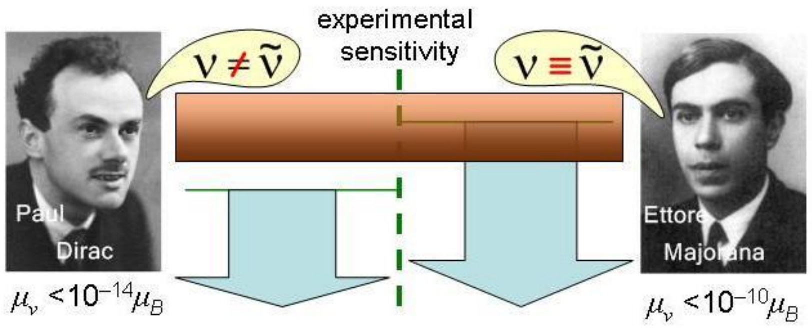




Magnificent CEvNS, Raimund Strauss



1: Magnetic moment diagram for Dirac neutrinos.



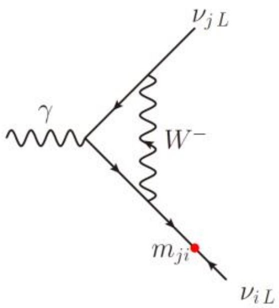
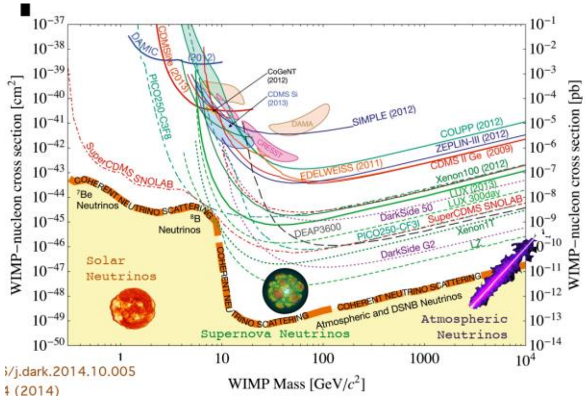
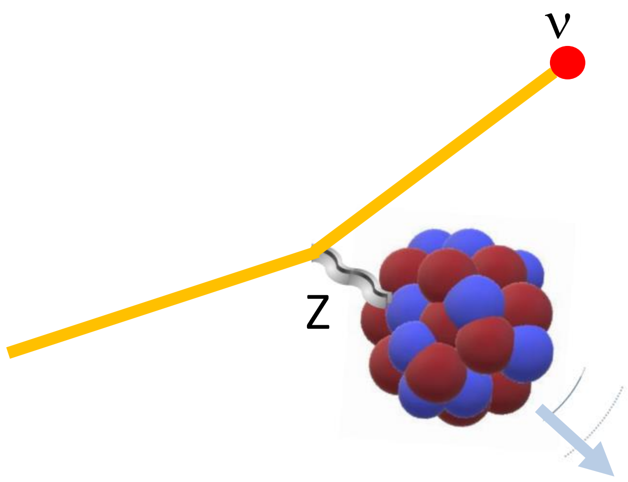


Figure 2: Magnetic moment diagram for Majorana neutrinos.



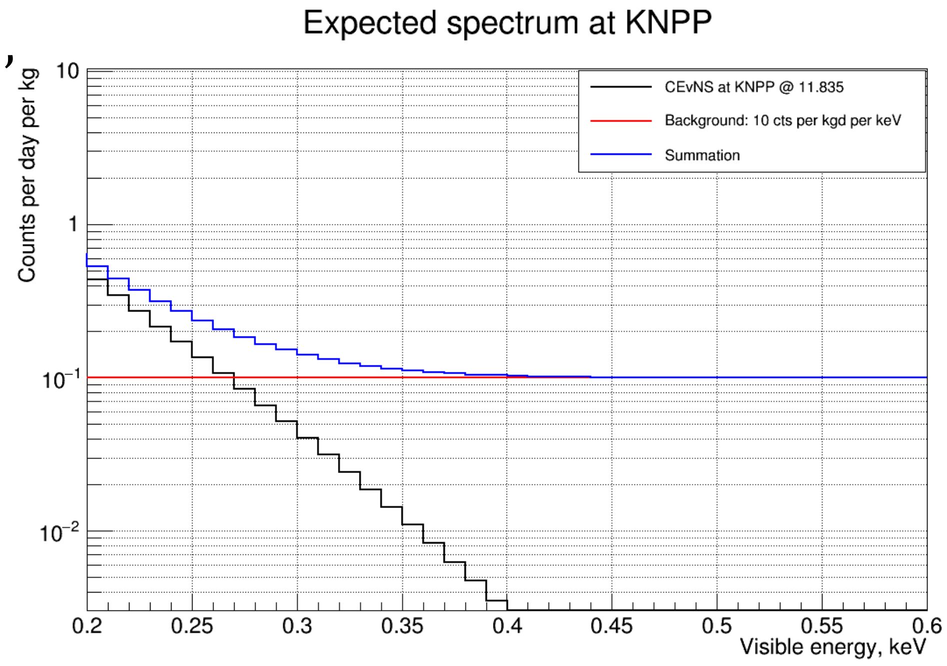
CEνNS

Coherent elastic neutrino-nucleus scattering is the process allowed in a Standard Model. Neutrino interacts coherently with nucleus as a single particle. This process was predicted in 1974 by Freedman [D. Freedman, Phys.Rev. D 9 1389 (1974)]. CEνNS cross-section:



$$\frac{d\sigma_{CE\nu NS}}{dT} = \frac{G_F^2 M}{2\pi}\left[2 - \frac{2T}{E_\nu} + \left(\frac{T}{E_\nu}\right)^2 - \frac{MT}{{E_\nu}^2}\right]\frac{Q_W^2}{4}F^2(Q^2)$$

$E_\nu - energy\ of\ neutrino,\ G_F\ - Fermi\ constant, M - mass\ of\ nuclues,\ F - nuclear\ form\ factor(\sim 1\ for\ CE\nu NS),$
$Q_W = N - (1 - 4sin^2\theta_W)Z \approx N - 0.045\,Z$
$sin^2\theta_W \sim 0.239\ (at\ low\ energy) - Weinberg's\ angle,\ N, Z - number\ of\ neutrons\ and\ nuclear\ charge$

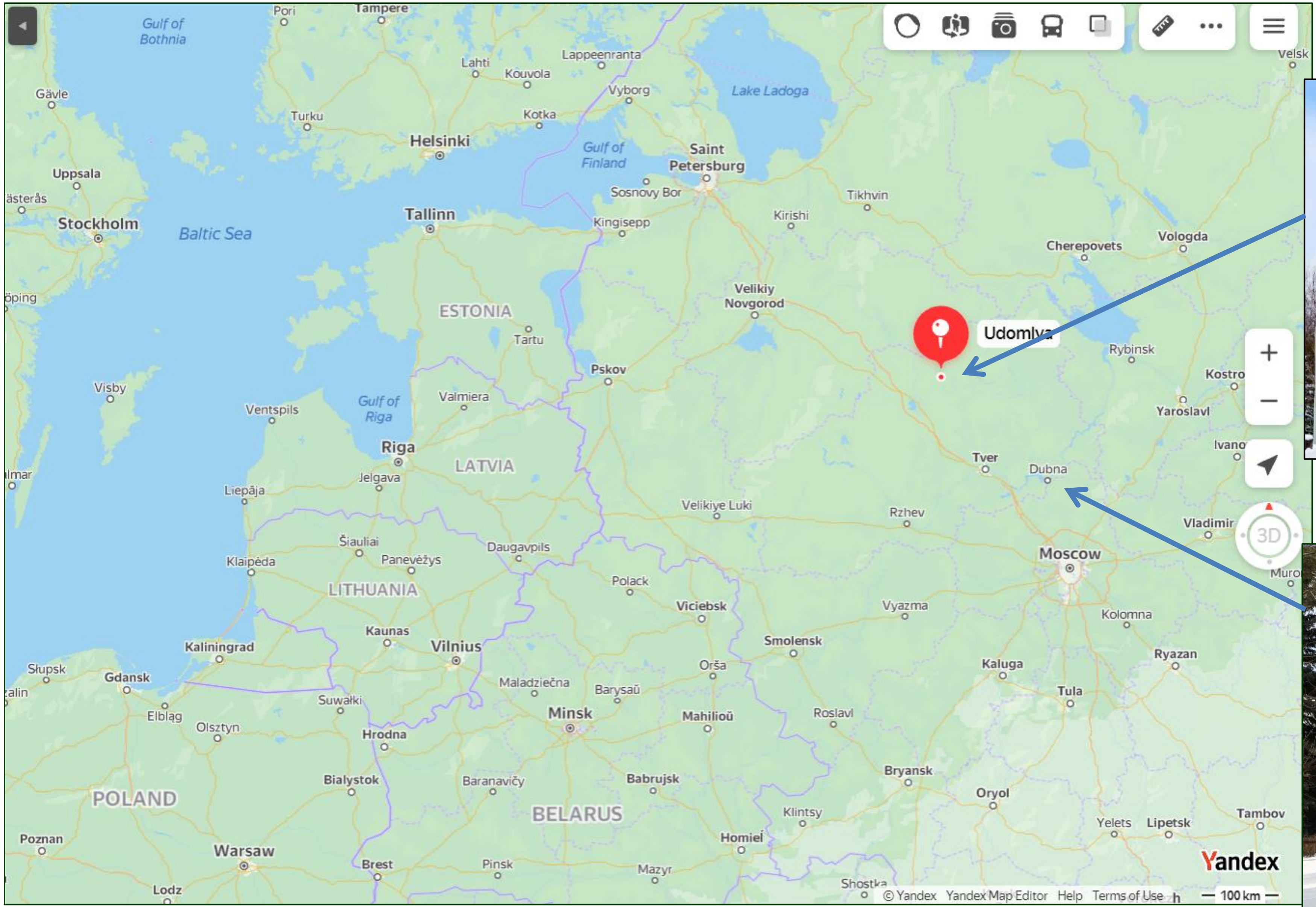


- Proportional to number of neutrons squared: N^2
- Several orders of magnitude higher that usual neutrino cross-section.
- CEνNS is a domination process of neutrino scattering at low energies (E_ν < 50 MeV)
- **Full coherency < 30 MeV**

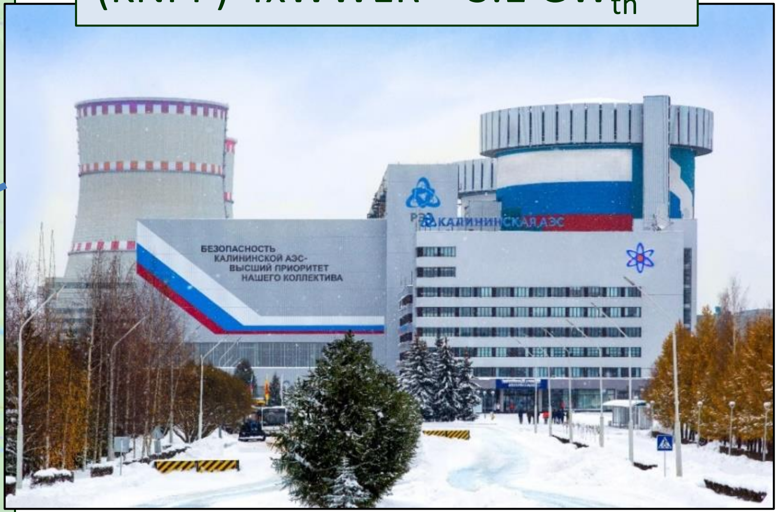
Detection of CEνNS

- Powerful neutrino source in full coherency regime < 30 MeV.
- Low threshold detector with good energy resolution.
- Low background
- Effective separation of signals from background
- Big mass and good efficiency
- Stable performance and knowledge of systematical errors.

νGeN reactor site at Udomlya, Russia



Kalinin Nuclear Power Plant (KNPP) 4xWWER – 3.1 GW_{th}



JINR, Dubna, 285 km from KNPP

Comparison of the reactor sites

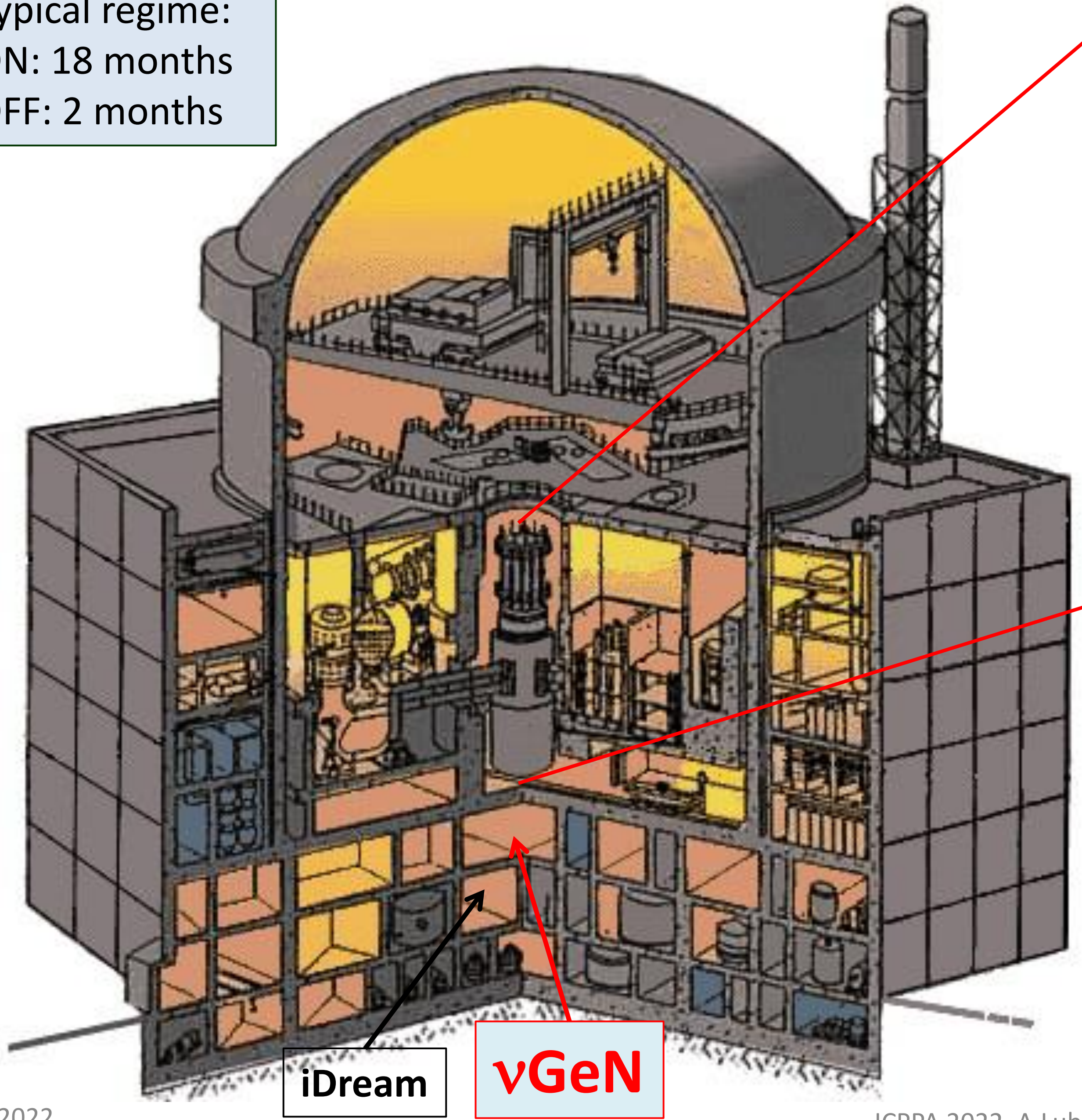
Experiment	Location	Neutrino flux $\nu/(cm^2\ s)$	Overburden [m w. e.]
νGeN	**KNPP, Russia**	**$\sim(4\text{-}5)\times10^{13}$**	**~50**
CONUS	Brokdorf, Germany	**2.4×10^{13}**	**10-45**
TEXONO	Kuo-Sheng NPP, Taiwan	**6.4×10^{12}**	**~30**
RED-100	KNPP, Russia	**1.7×10^{13}**	**>50?**
CONNIE	Angra 2, Brazil	**7.8×10^{12}**	**0**
RICOCHET	ILL, France	**2×10^{12}**	**~15**
MINER	Texas A&M, USA	**2×10^{12}**	**~5**
NUCLEUS	Chooz, France	**2×10^{12}**	**~3**
Dresden 2	Dresden-II, USA	**4.8×10^{13}**	**-**
NEON	Hanbit 6, Korea	**7.1×10^{12}**	**~8**
SBS	Laguna Verde, Mexico	**3×10^{12}?**	**?**

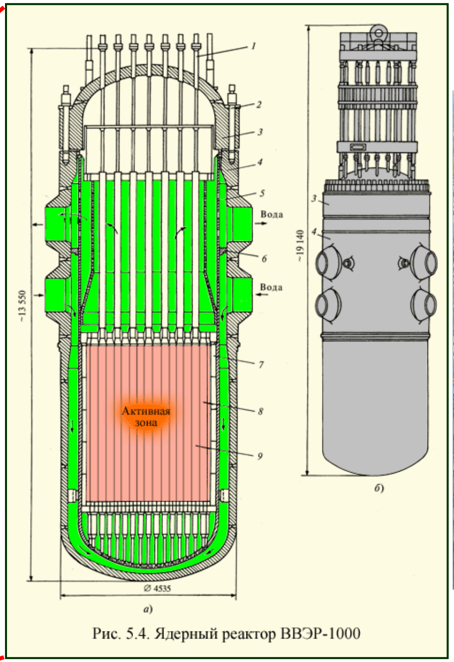
νGeN collaboration

Joint Institute for Nuclear Research, Dubna, Russia
Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia
Institute of Experimental and Applied Physics, Czech Technical University in Prague

Reactor unit #3 @ KNPP

Typical regime:
ON: 18 months
OFF: 2 months

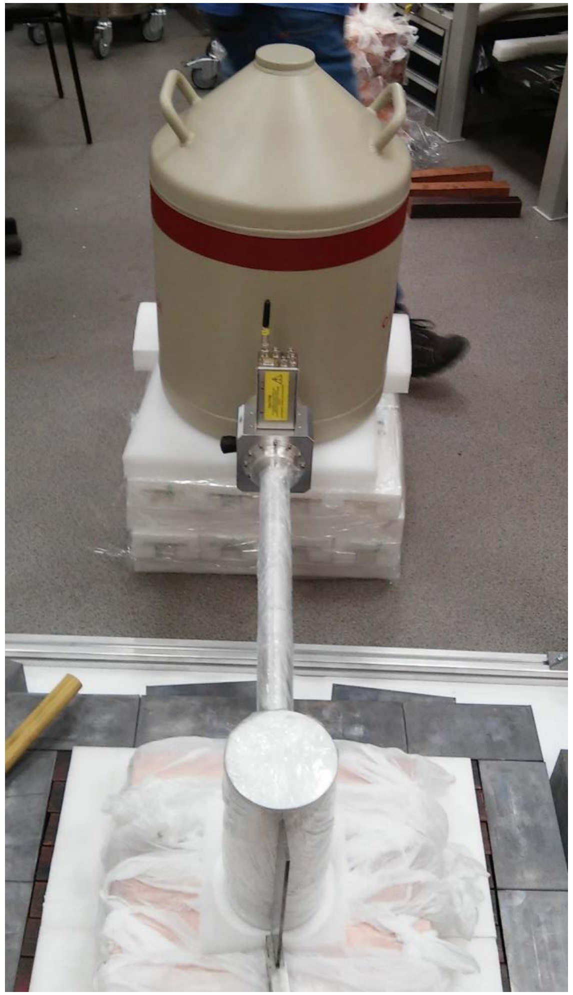




- Spectrometer **νGeN** is located under the reactor unit #3 (3.1 GW_{th} – thermal power)
- Distance to the center of reactor core is about 11 m, this gives **~ $5 \cdot 10^{13}$ ν/(sec·cm^2)**
- Overburden ~ **50 m w.e.** – good shielding against cosmic radiation due to reactor's surrounding
- Good support from KNPP administration

HPGe detector for νGeN

To detect signals from neutrino scattering we use a specially produced by CANBERRA (Mirion, Lingosheim) low-threshold, low-background HPGe detectors. The detectors are chilled by electric and nitrogen types of cooling. At the moment at KNPP only one detector with mass of 1.4 kg and e-cooling is used for the detection.



Current scheme of νGeN shielding

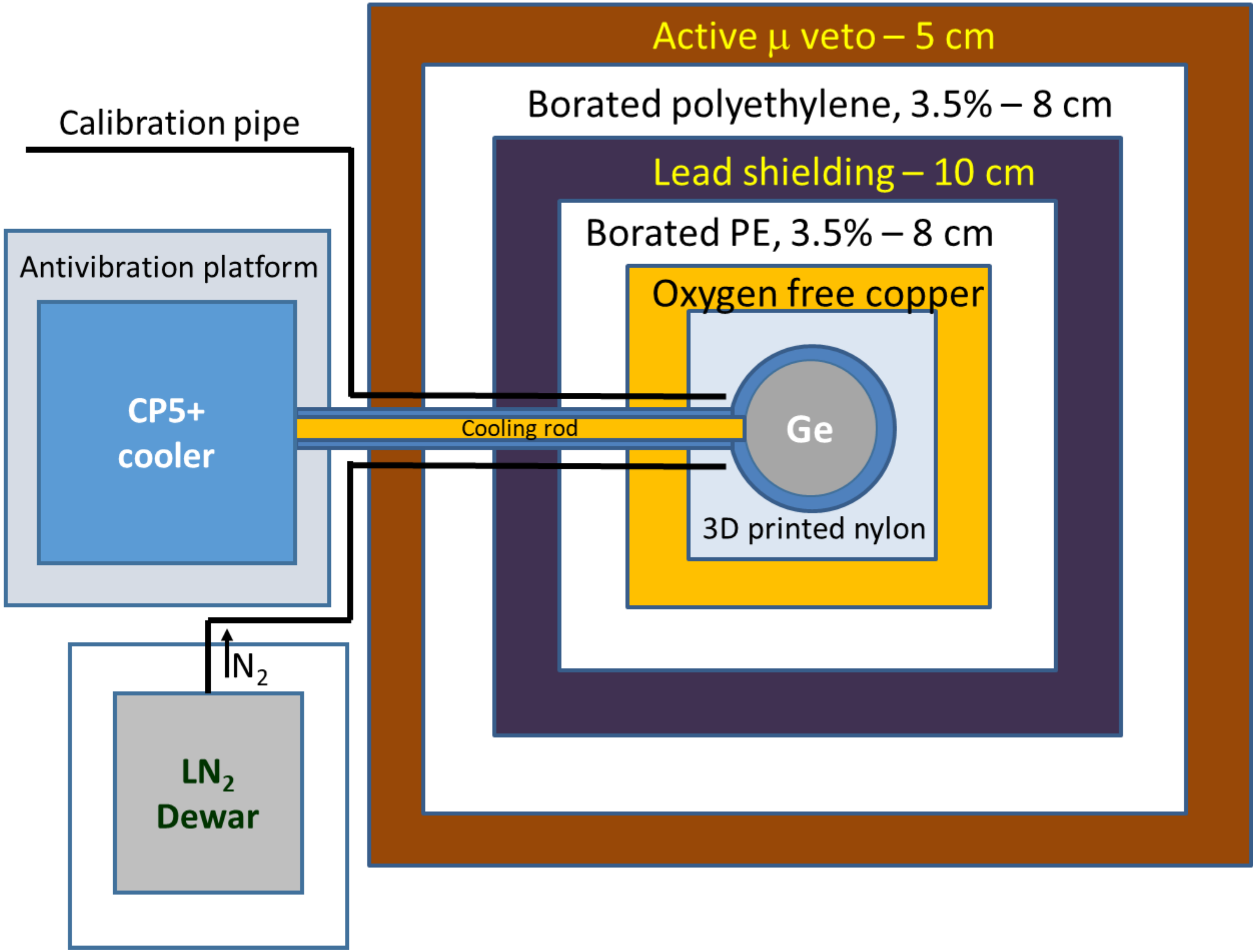
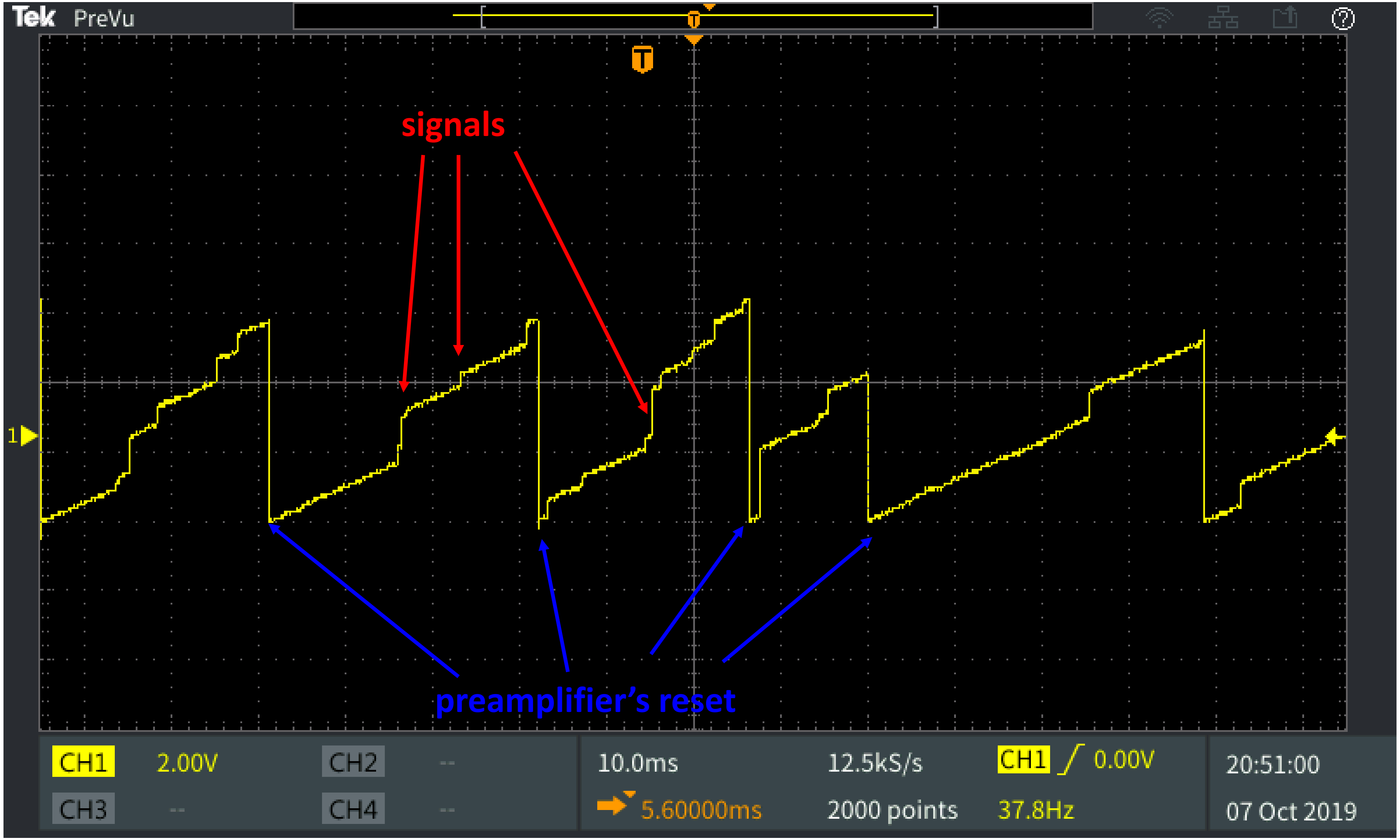


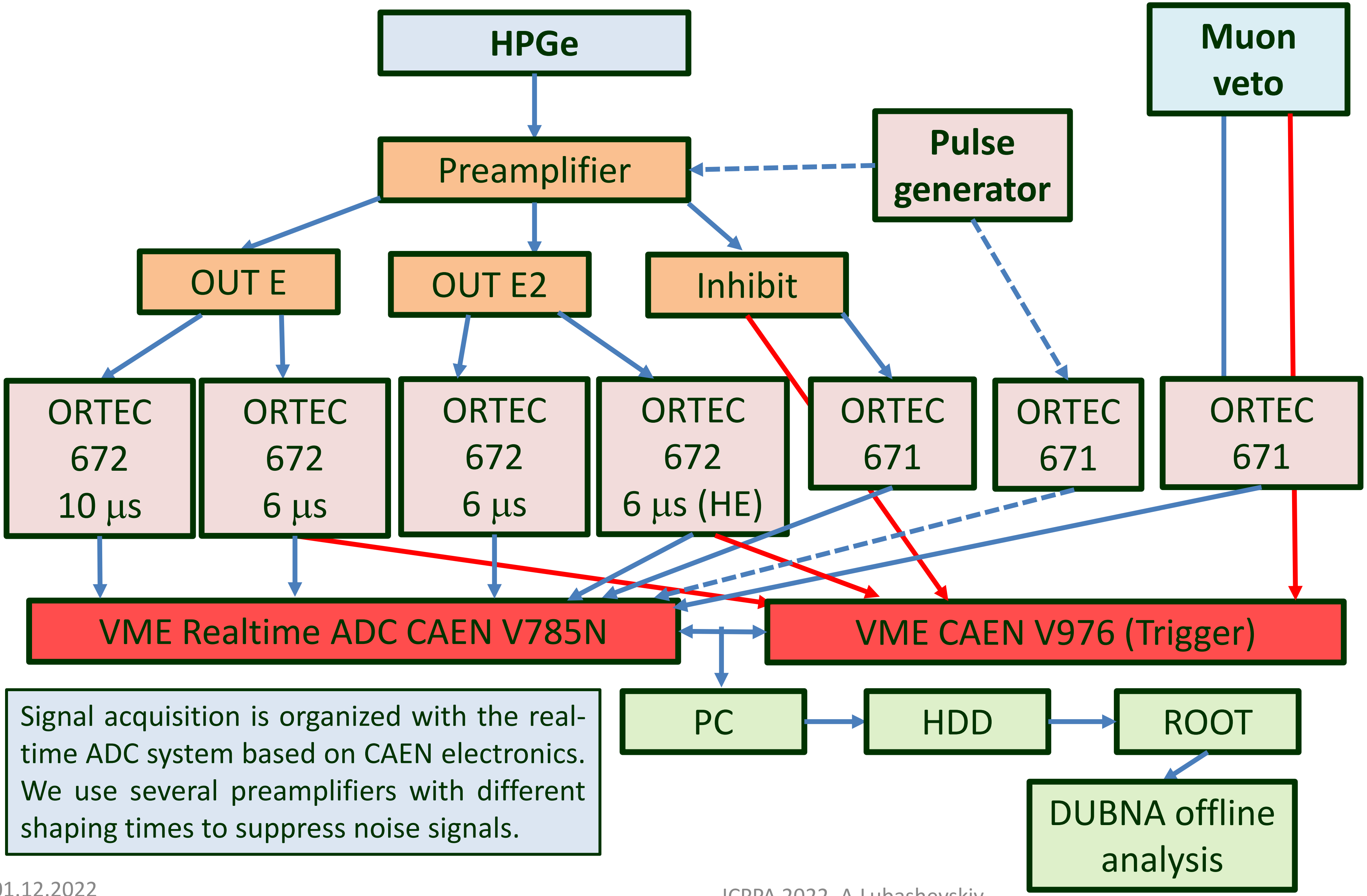
Photo from installation at KNPP in 11.2019

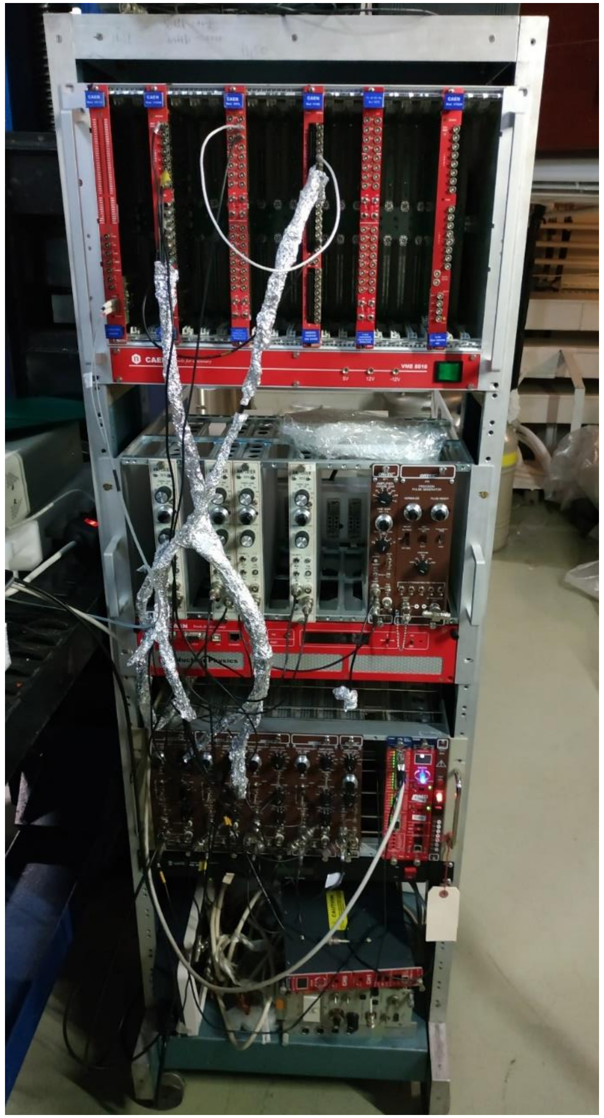
Signals from detector



- Detectors are equipped with reset preamplifier.
- A typical rate of reset is ~ 5 Hz
- There is a special inhibit signal that indicates the time when the reset happens.
- The signals are shaped with amplifiers and processed with a real-time ADC.

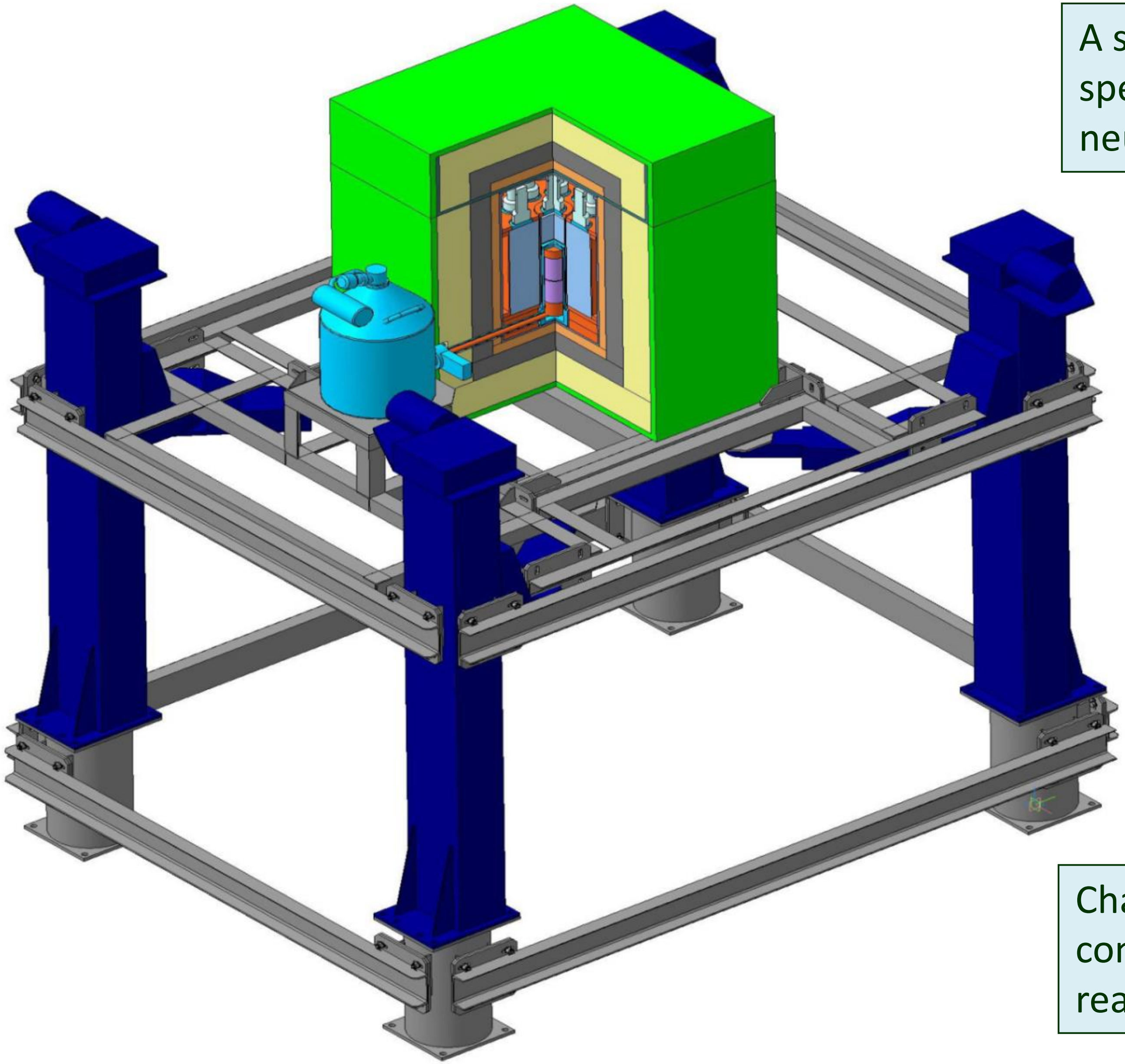
Simplified scheme of measurements





Signal acquisition is organized with the real-time ADC system based on CAEN electronics. We use several preamplifiers with different shaping times to suppress noise signals.

νGeN @ KNPP – lifting mechanism



A special lifting mechanism has been installed to move the spectrometer towards the reactor core to change the neutrino flux through the detector.

10.830 m – top position (current)

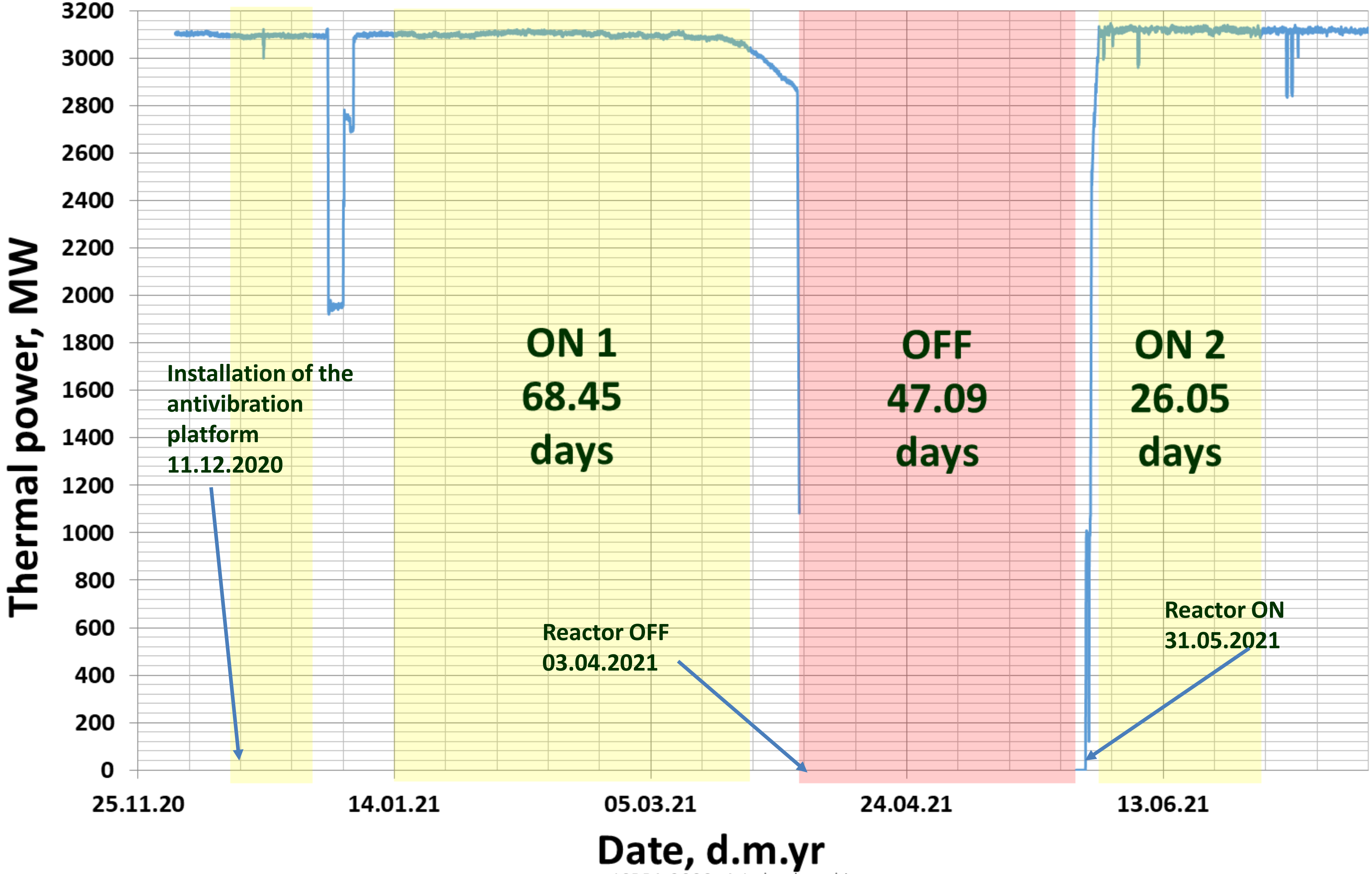
11.835 m – current data

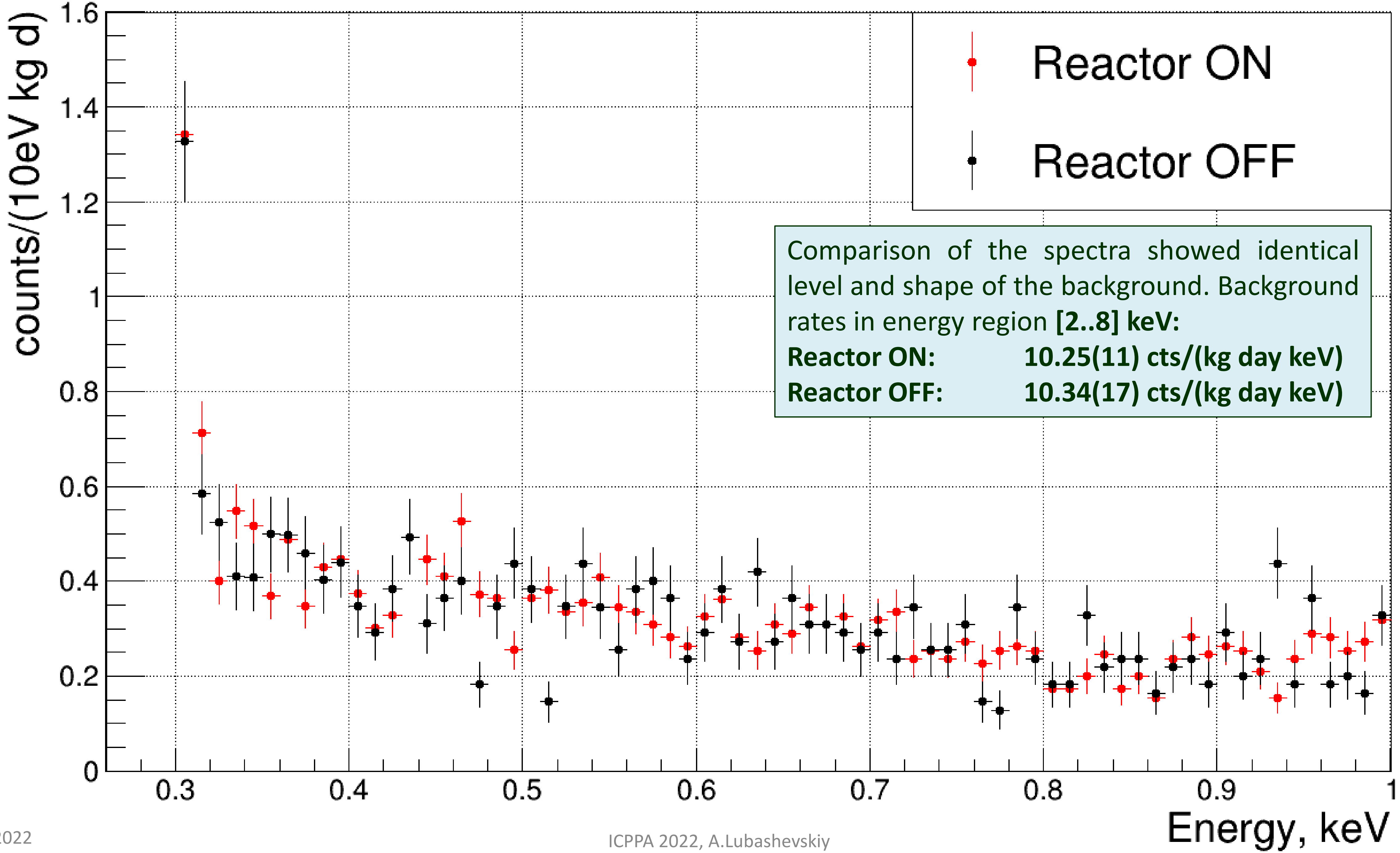
11.935 м – lower position

Distances to the center of reactor core:

Changes of the ν flux help to suppress systematic errors connected with changes of the background while the reactor ON/OFF

Time changes of the thermal power of reactor unit #3

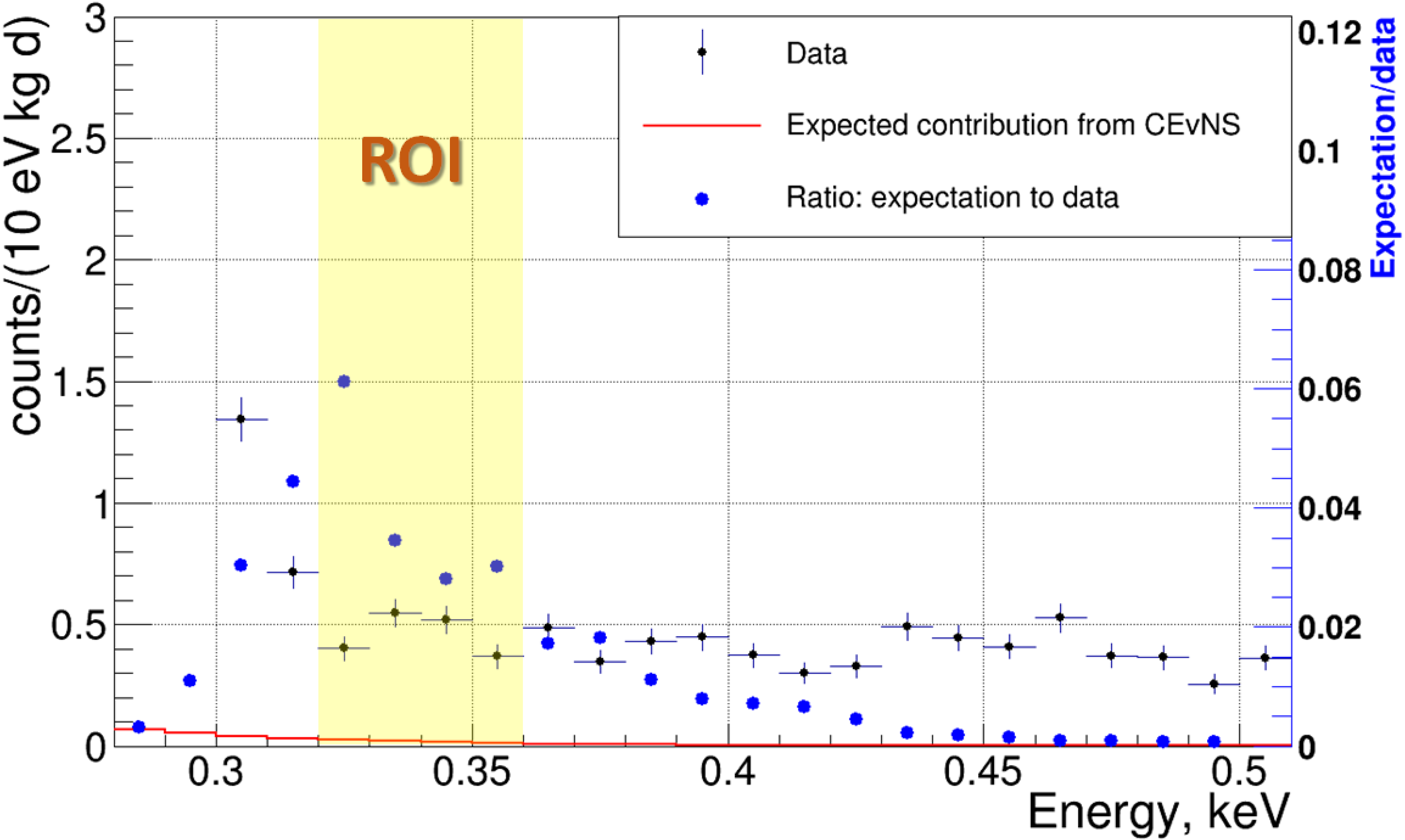




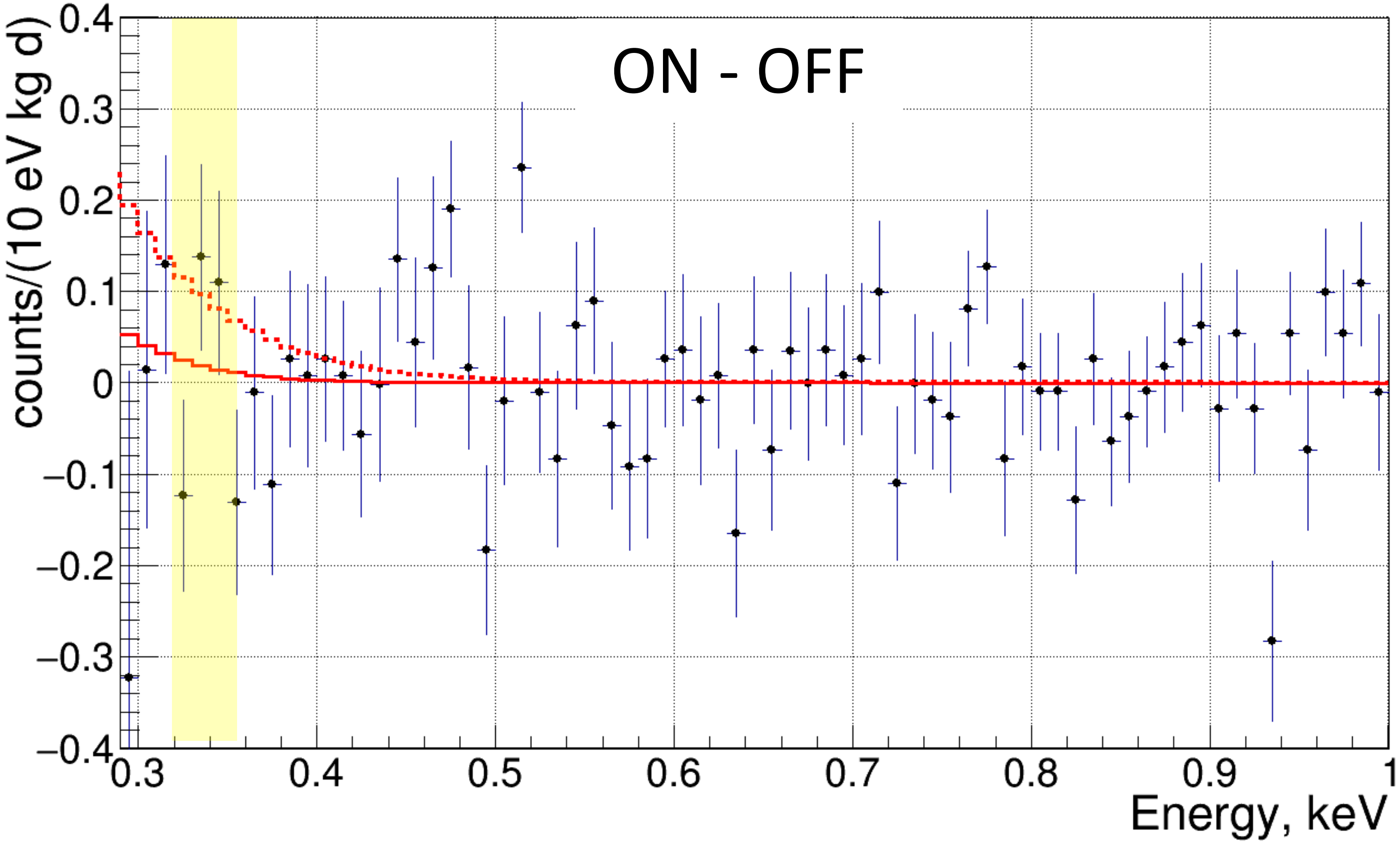
Comparison of the spectra showed identical level and shape of the background. Background rates in energy region **[2..8] keV:**

Reactor ON: **10.25(11) cts/(kg day keV)**

Reactor OFF: **10.34(17) cts/(kg day keV)**



ROI
Data
Expected contribution from CEvNS
Ratio: expectation to data
counts/(10 eV kg d)
Expectation/data
Energy, keV
0
0.5
1
1.5
2
2.5
3
0.3
0.35
0.4
0.45
0.5
0.02
0.04
0.06
0.08
0.1
0.12



Analysis of the first data shows no significant difference in background level during reactor on and off regimes. No excess at low energy connected with the CEvNS has been observed. The upper limit on the quenching parameter **k < 0.26** with 90% CL has been obtained (dashed line). Red solid line k = 0.179.

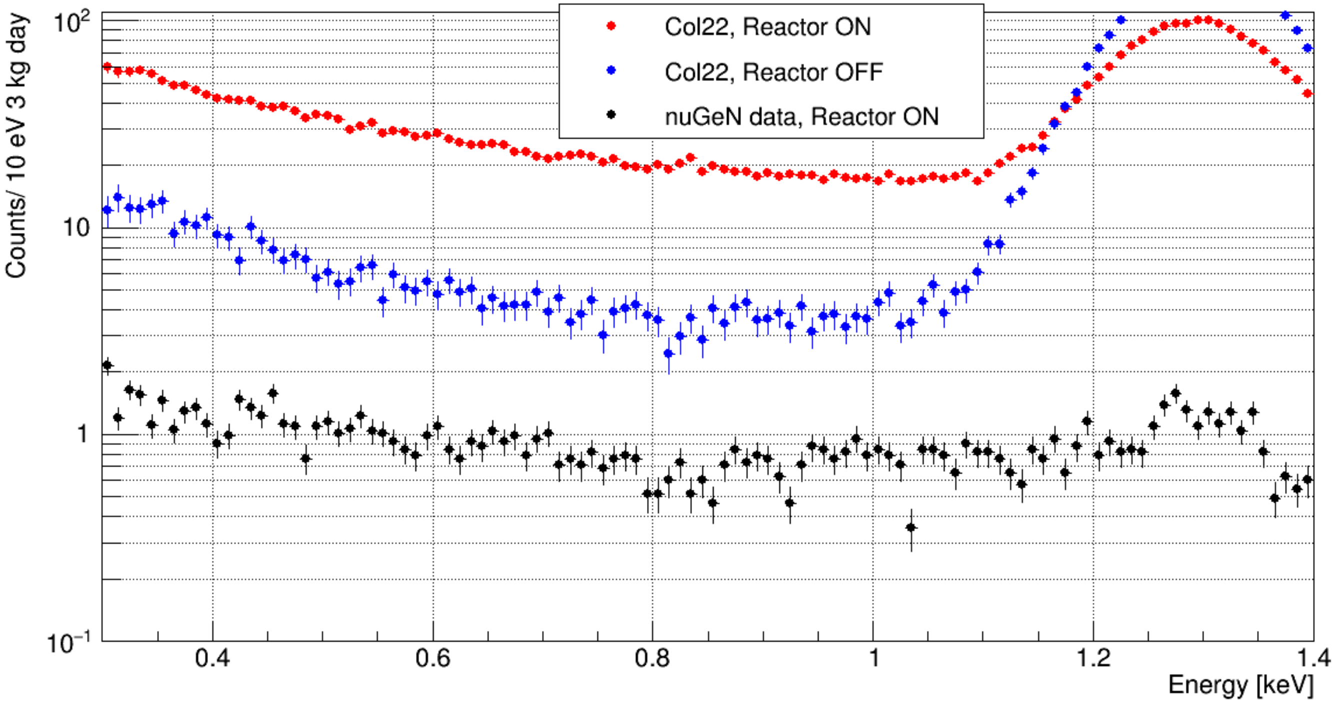
	Counts in region [320..360] eV	Measurement time, days	Counts per kgd (stat. error only)
Reactor ON	**251**	**94.5**	**2.32 ± 0.15**
Reactor OFF	**126**	**47.1**	**2.34 ± 0.21**
Subtracted			**-0.017 ± 0.255**
CEvNS, k = 0.26	**55**		**0.46**

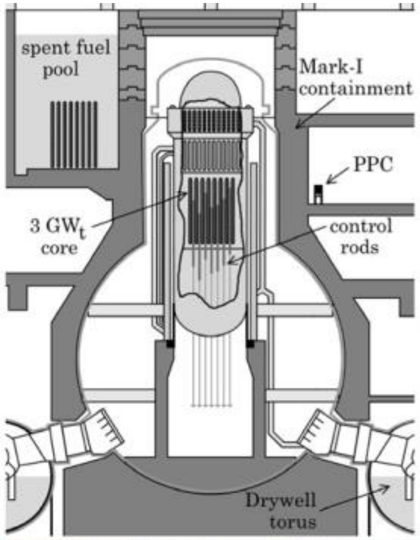
Conclusion

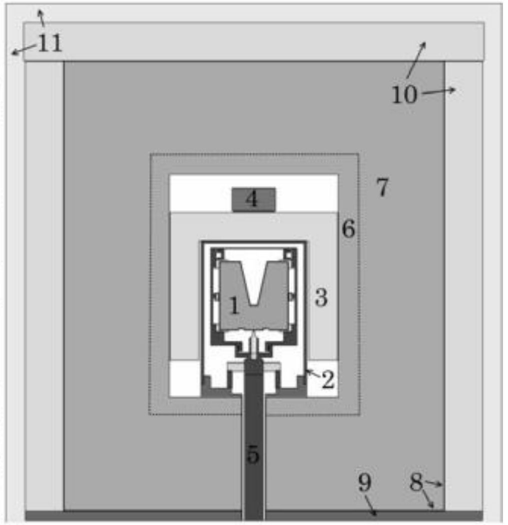
- Measurements with νGeN spectrometer at Kalinin Nuclear Power Plant is ongoing.
- First results showed that achieved background level allows to search for CEνNS at KNPP. No significant difference between regimes with reactor ON and OFF has been observed so far.
- The upper limit on the quenching parameter **k < 0.26** with 90% CL has been obtained.
- Lifting mechanism was completed and since 09/2022 we perform data taking at reduced distance to the reactor core (10.8 m from the center of reactor core).
- The optimization of data taking is performed as well. New results with more statistics are expected soon.

J. Colaresi, J. I. Collar,* T. W. Hossbach , C. M. Lewis , and K. M. Yocum, «Measurement of Coherent Elastic Neutrino-Nucleus Scattering from Reactor Antineutrinos», PHYSICAL REVIEW LETTERS 129, 211802 (2022)

- Claimed about strong preference ($p<1.2\cdot10^{-3}$) for the presence of CEvNS.
- Similar to nuGeN antineutrino flux from reactor (4.8 10^{13} ν/cm2/sec)
- Sideway location gives almost no overburden (cosmogenic background).
- Almost no shielding against fast neutrons.
- No the same shielding configuration during reactor ON and OFF
- Big difference in background levels during reactor ON and OFF
- Moderate energy resolution ~ 160 eV (FWHM) (in nuGeN – 101.6(5) eV)







Спасибо!