COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING SEARCH IN THE νGeN EXPERIMENT.

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The νGeN experiment aims to search for coherent elastic neutrino-nucleus scattering and to study the other rare processes. The experimental setup is located about 12 meters from the center of the 3.1 GWth reactor №3 of Kalinin NPP providing the antineutrino flux of $(3.6–4.4)\cdot10^{13}$ particles$\cdot$cm$^{-2}\cdot$s^{-1}. The intense antineutrino flux gives a possibility to detect coherent elastic scattering of reactor antineutrinos on Ge nuclei in the regime of full coherence, as well as to study other properties of neutrinos

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Introduction

The coherent elastic neutrino-nucleus scattering (CEνNS) is the process which was predicted theoretically 50 years ago [1]. The coherency effect takes place when $QR << 1$, where R is a nuclear radius and Q is a transferred momentum. CEνNS was discovered in 2017 (but not in the region of complete coherence) by the COHERENT experiment [2]. This process is extremely difficult to detect, due to very low energy transferred by neutrino to a nucleus. Depending on the nucleus and neutrino kinetic energy, this energy can be either a few keV or even less than keV. Due to quenching, only a minor part of the transferred energy contributes to ionization. This makes detecting CEνNS challenging, necessitating the use of low background detectors with extremely low thresholds and a potent neutrino source. An accurate measurement of CEνNS can be a key to the physics beyond the Standard Model. The anomalous neutrino magnetic moment, higher than 10^{-15} μ_B will also indicate the existence of a new physics [3].

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Experiment

The νGeN experiment was deployed at the Kalinin nuclear power plant under reactor №3, which has a power of 3.1 GW$_{th}$ [4]. The distance to the center of the reactor core is about 11 meters from the floor of the experimental hall. In this hall it is possible to operate with antineutrino flux up to $4.4{\cdot}10^{13}$ particles$\cdot$cm$^{-2}\cdot$s^{-1}. The reactor and its building provide about 50 meters of water equivalent shielding against cosmic radiation [5].

To detect CEνNS, a 1.4 kg HPGe low-threshold, low-background detector is used in the νGeN experiment. The detector is cooled to a cryogenic temperature by the cryocooler CP5+ [6]. The detector shielding against radioactive background consist of 3D printed nylon as inner layer (antiradon shielding), 10 cm of oxygen-free high-purity copper, 8 cm of 3 % borated polyethylene, 10 cm of lead, another 8 cm of 3 % borated polyethylene and 5 cm thick plastic muon veto. The nitrogen flushing of the internal volume of the shield allows to suppress potential radon-related backgrounds. The cryocooler is placed on antivibration platform TS-C30 [7] to reduce mechanical noises of the KNPP equipment. The experimental hall is equipped with air conditioners to provide a stable temperature. Scheme of the shielding is presented in figure 1.

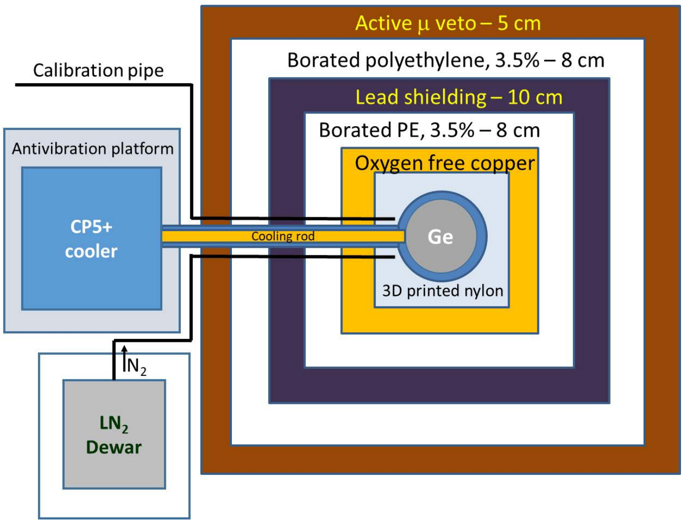

Fig. 1. Scheme of the shielding of the νGeN experiment

To suppress electronic noises the several amplifiers with different shaping times connected to the real time ADC are used. The energy scale is calibrated using a welding tungsten rod, cosmogenic isotopes of germanium, and a pulse generator. The energy resolution of the pulse generator signals is 101.6(5) eV (FWHM). The detection efficiency for signals from events with energy higher than 250 eV is more than 80 %. The efficiency of the applied cuts, as determined by 10.37 keV cosmogenic line, is 85.3(19) %.

The whole setup is mounted on the special lifting mechanism (figure 2), which allows to change the distance between spectrometer and the center of the reactor core from 11.1 to 12.2 meters. Thus, we can change the antineutrino flux passing through the detector (3.6–4.4)$\cdot 10^{13}$ particles$\cdot$cm$^{-2}\cdot$s^{-1}.

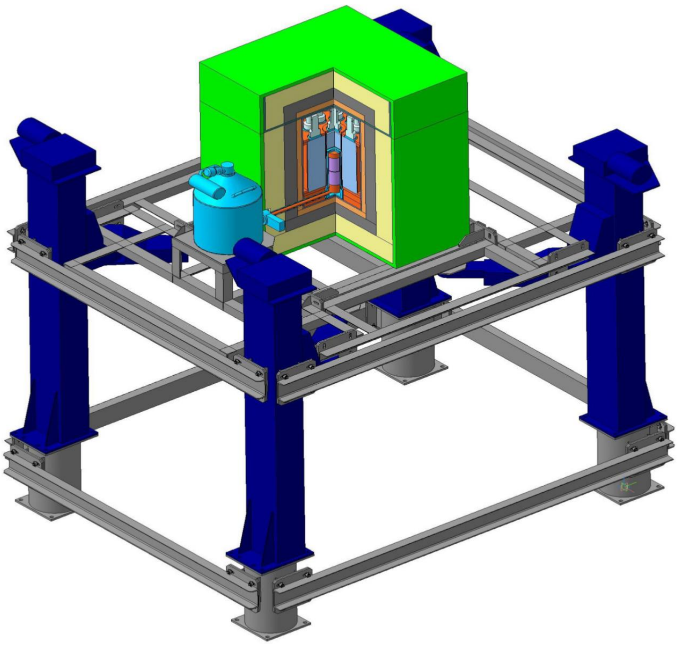

Fig. 2. Scheme of the lifting mechanism.

Results

Up until 2022, measurements were conducted at a distance of 11.84 meters from the reactor core. At this location, data corresponding to 94 kg·days days with the reactor operational and 47 kg·days days with the reactor non-operational were collected after implementing all cuts. The analysis focused on the energy range of 0.32–0.36 keV. No CEνNS signal was detected, leading to the establishment of an upper limit on the quenching parameter k$<$0.26 [4].

In the fall of 2022, upgrades were implemented that enhanced noise and background levels. Following these improvements, the spectrometer was relocated to a higher position (11.09 meters). In this new position, data from 217 kg·days with the reactor operational and 55 kg·days with the reactor non-operational were analyzed. The sensitivity to CEνNS was assessed using the reactor OFF spectrum (55 kg·days) and Azimov data sets, which include generated CEνNS spectra combined with the OFF spectra. The statistical analysis was based on the same dataset size as the current one (217 kg·days).

In new data the region of interest 0.29–0.36 was chosen, thanks to a lower noise with respect to the previous measurements. The excess in the count rate during reactor ON was not observed (figure 3).

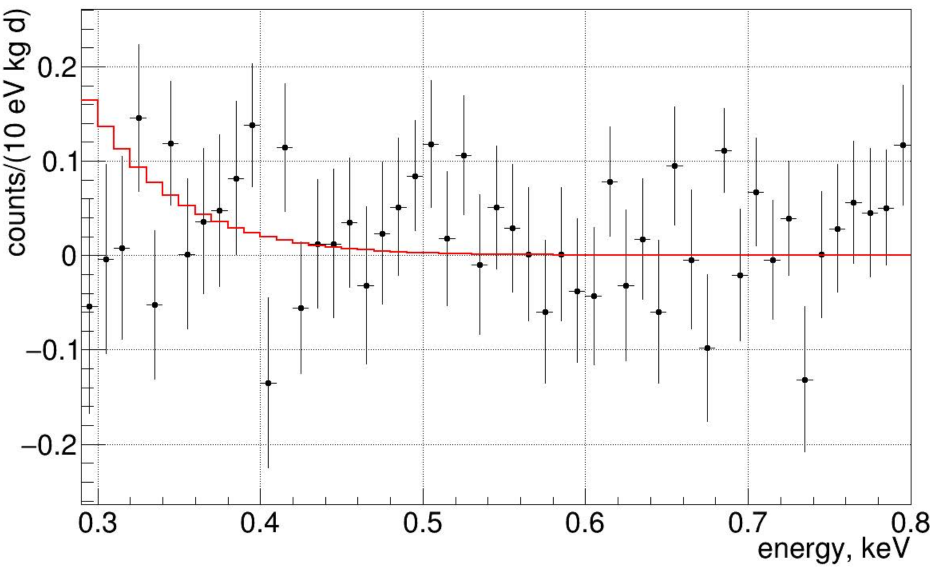

Fig. 3. The residual spectrum of the νGeN experiment data collected in the upper position. Black dots with errors−experimental data. Red solid line−expected CEνNS spectra, in case of the quenching parameter k=0.23.

Conclusion

Measurement with the νGeN spectrometer is ongoing. More than 1200 kg·days of data has been accumulated so far. The spectrometer demonstrates good performance. The background level during reactor ON and OFF regimes is stable. The combined analysis of data taken in the lower and upper positions will be presented soon, as well as results of the study of neutrino electromagnetic properties. It is planned to install new digitizer based DAQ and inner veto. This work has been partly supported by the Ministry of science and higher education of the Russian Federation.

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