Development of the reactor antineutrino detection technology within the iDream project.

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Abstract. The iDREAM (industrial Detector for reactor antineutrino monitoring) project is aimed at remote monitoring of the operating modes of the atomic reactor on nuclear power plant to ensure a technical support of IAEA non-proliferation safeguards. The detector is a scintillator spectrometer. The sensitive volume (target) is filled with a liquid organic scintillator based on linear alkylbenzene where reactor antineutrinos will be detected via inverse beta-decay reaction. We present first results of laboratory tests after physical launch. The detector was deployed at sea level without background shielding. The number of calibrations with radioactive sources was conducted. All data were obtained by means of a slow control system which was put into operation.

1. Introduction
The detector iDREAM (industrial Detector for REactor Antineutrino Monitoring) was developed to demonstrate and to prove the ability of the remote control of the atomic reactors by means of the antineutrino flux irradiated from the core of the reactor. Additional information about the design and the other properties have been described in the following paper [1].

2. Physical Start-up of the detector.
Main investigations of the methods of development of a Liquid Organic Scintillator (LOS) on the base of Linear Alkyl Benzene (LAB) have been finished by the middle of 2017 and the LOS without gadolinium for the target of the detector has been synthesized. As a first scintillation admixture was used PPO (C\textsubscript{15}H\textsubscript{11}ON) in the following concentration 3 g/l, as a second admixture was bis-MSB (C\textsubscript{24}H\textsubscript{22}) with concentration 20 mg/l.

2.1. Measurements of the main physical parameters of the detector. A subsection
The target of the detector was filled with the scintillator, the circle volume was filled with pure LAB. The target volume PMTs were installed and connected to the DAQ system. On the first stage a setup of working voltage of PMTs was conducted. The high voltage (HV) was adjusting individually for each PMT in accordance with Monte-Carlo simulation. For the PMTs voltage set up \textsuperscript{137}Cs (E\textsubscript{γ}=662 keV) was used. The source was placed in the center of the target.

After the completion of the setup the HV was applied for all PMTs. The spectrum of the total signal is shown on the figure 1. A blue line is representing the cumulative spectrum of the \textsuperscript{137}Cs with background (BG), a red line is BG, a green line is the "pure" source spectrum (the BG subtracted). To achieve the peak position, the standard deviation and the energy resolution of the detector, the "pure" spectrum was fitted with the Gaussian distribution, so the values for the energy distribution with
energy 662 keV are 612.9 and 47.55 for the peak position and the standard deviation respectively, thus the energy resolution is 7.8%.

| Cs-137     |
|------------|
| Entries   1500 |
| Constant  2042 |
| Mean      612.9  |
| Sigma     47.55  |

Figure 1. Energy spectrum of the $^{137}$Cs in the center of the iDREAM target.

For the detector calibration the $^{207}$Bi source was used and it let to determine the detector response in the energy region from 500 keV to 2500 keV. The obtained energy spectrum of $^{207}$Bi (BG subtracted) are represented in figure 2, where is also represented $^{137}$Cs spectrum. Both of the sources were placed in the center of the detector.

Figure 2. Energy spectrum of $^{137}$Cs and $^{207}$Bi in the center of the detector.

The peak 662 keV corresponds to a single gamma. Spectrum region around 1634 keV and 2340 keV forms with two cascade gammas with energies (1064 keV + 570 keV) and (1770 keV + 570 keV) respectively.
Around the energy ~600 keV, the spectrum of $^{207}$Bi consists of three types of radiation:

- single gamma with energy 570 keV (~6.7%);
- two gammas: 570 keV + 88 keV = 685 keV (~7.4 %);
- two gammas 570 keV + 15 keV = 585 keV (~2.3%).

The average irradiated energy in this region is ~612keV.

For setups, which use LOS as a target is typical a little nonlinearity of the response function of the detector especially below ~1MeV. The response function of the iDREAM was based on the measurements of the calibration of $^{207}$Bi and $^{137}$Cs within the 0.5-2.5 MeV energies. The results are represented in figure 3, where a true energy of gammas is on the X-axis and the ratio of visible to true energy is on the Y-axis.

![iDREAM: $^{137}$Cs and $^{207}$Bi in the center](image)

**Figure 3.** The ratio visible energy to true energy for $^{207}$Bi and $^{137}$Cs in the iDREAM.

We can see on the figure 3, that besides "usual" nonlinearity an additional decrease of the ratio for the gammas of the $^{207}$Bi is observed. It can be explained, that $^{207}$Bi irradiates two gammas, each of them gives an impact in the nonlinearity effect during the registration in the liquid scintillator.

The important characteristic is a nonuniformity of a light gathering in the detector. To measure this parameter we used $^{137}$Cs, which was moving along the center vertical axis with a pitch of 10 cm and also along the vertical axis in the circle volume close to the target volume wall.
Final results are represented in figure 4. Blue points represent the calibration data along the central axis, red points represent the data along the axis in the circle volume. The maximum difference of the measured energy in the target is 13%.

3. Conclusion.
The physical startup of the detector iDREAM has been conducted successfully. We have measured the general parameters of the detector, such as the energy resolution (7.8%), the response function (figure 2) and the nonuniformity of the energy scale (figure 3) The results correspond with the parameters which were factored in the design.

Acknowledgments.
This work was supported by NRC "Kurchatov institute" within the R&D "The development of the Slow-Control system of the detector iDREAM for the remote monitoring of the atomic reactors".

References
[1] Gromov M B et al. 2015 Moscow Univ. Phys. 70 190