PROCEEDINGS OF SCIENCE

Recent results of the DANSS experiment

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We present the new results of the DANSS experiment on the searches for sterile neutrinos. The results are based on approximately 5.5 million of inverse beta decay (IBD) events collected during 5 years at 10.9, 11.9 and 12.9 meters from the reactor core of the 3.1 $\mathrm{GW_{th}}$ Kalininskaya Nuclear Power Plant in Russia. In the closest position to the reactor core more than 5000 IBD events per day are collected with the signal to background ratio above 50. The best fit with 4ν hypothesis corresponds to $\Delta m^2 = 1.3$ eV^2 and $\sin^2 2\theta = 0.014$. It has $\Delta\chi^2 = -3.2$, which corresponds to less than 1.3σ effect. This means that no statistically significant evidence of oscillations observed so far. An exclusion region was calculated using the Gaussian CLs method and reaches $\sin^2 2\theta = 0.008$ around $\Delta m^2 = 0.9$ eV^2 at the 90% confidence level. We have also measured the reactor power using the IBD event rate during 4.5 years with the average statistical accuracy 1.9% in 2 days and with the relative systematic uncertainty below 0.5%. Plans for the DANSS upgrade are presented also. The upgrade should allow DANSS to test the Neutrino-4 claim of observation of sterile neutrinos.

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1. Introduction

Experimental study of neutrinos is always very interesting. Due to tiny interaction cross sections neutrinos provide a very clean picture, based on the most fundamental laws of the Nature, not smeared by secondary effects. This makes neutrinos a very perspective tool of discovery. But the same weakness of interactions makes experiments with neutrinos very difficult, requiring a strong neutrino beam together with a sizable target. Industrial reactors are one of the best places for neutrino experiments, providing a flux of $\sim 5 \cdot 10^{13} \nu \mathrm{cm}^{-2}\mathrm{c}^{-1}$ at 11 m from the core. Experiment DANSS is placed below the 4^{th} reactor unit of Kalininskaya NPP 350 km NW from Moscow, Russia. This is an excellent position providing both a high flux of antineutrinos and a moderate protection from the cosmic muons ($\sim$ 50 m.w.e). The detector has a cubic meter sensitive volume assembled from 2500 polystyrene scintillator strips with dual readout by silicon and conventional photo-mulipliers (SiPM and PMT). SiPMs read each strip individually through a wavelength shifting fiber placed along the central groove of the strip. Two side fibers from 50 neighbor strips are joined together and lead to a PMT. The sensitive volume is surrounded by a multilayer passive shielding from copper, borated polyethylene and lead. Five sides of the detector with the exception of the bottom side are covered by the active shielding made of scintillator counters. The detector is placed on a movable platform, which allows to change the distance from the DANSS center to the center of the reactor core in the range 10.9-12.9 m. More details on the detector setup could be found in [1]. The information about the analysis and already published results is published in [2–4].

2. Search for sterile neutrinos

The most attractive feature of neutrino experiments is a search for the New Physics. The number of neutrino types in the Standard Model is trustfully fixed at the level of 3 and their oscillation parameters are well known [5]. Nevertheless there are several experimental hints in favor of the existence of one more neutrino flavor, which does not participate even in a weak interaction and manifests itself in short range oscillations [6]. In this case the survival probability of a neutrino is given by a familiar expression:

$$P(L) = 1 - \sin^2 2\theta_{ee} \sin^2 \left(\frac{1.27 \Delta m^2_{41} [\mathrm{eV}^2] L[\mathrm{MeV}]}{E[\mathrm{MeV}]} \right) \tag{1}$$

More recent evidences in favor of the neutrino disappearance described by this equation were obtained in reactor [7] and gallium [8] experiments, though other reactor experiments give no support [9–12].

DANSS analysis for sterile neutrinos is started from the creation of a χ^2 as a function of 4ν oscillation parameters Δm^2_{41} and $\sin^2 2\theta_{ee}$ using DANSS spectra measured at 3 distances as described in [13]. Systematic uncertainties were treated as nuisance parameters with corresponding penalty terms added to the χ^2. The whole list of the nuisance parameters with corresponding errors is given in table 1. The distribution of the χ^2 in the $(\Delta m^2_{41}, \sin^2 2\theta_{ee})$ plane calculated from 3975320 IBD events in the positron energy range 1.5 – 6.0 MeV is shown in fig. 1. The best point is at $\Delta m^2_{41} = 1.3$ eV^2 and $\sin^2 2\theta_{ee} = 0.014$ with $\Delta\chi^2 = -3.2$, which is less than 1.3σ. So no statistically significant oscillation signal is seen so far. The Gaussian CLs method [14] is used to obtain the exclusion region shown in fig. 2. We exclude large and interesting portion of the 4ν oscillation parameter space. The best point from the combined fit to gallium and reactor anomalies [15], shown by a star in fig. 2, has $\Delta\chi^2 = 107$, which means much more than 5σ exclusion.

Table 1: The nuisance parameters and their errors.

Parameter	Error	Parameter	Error
Energy scale	2%	Relative detector efficiencies	0.2%
Energy shift	50 keV	Additional smearing in the energy resolution	25%
Cosmic background	25%	Distance to the fuel burning profile center	5 cm
Fast neutron background	30%		

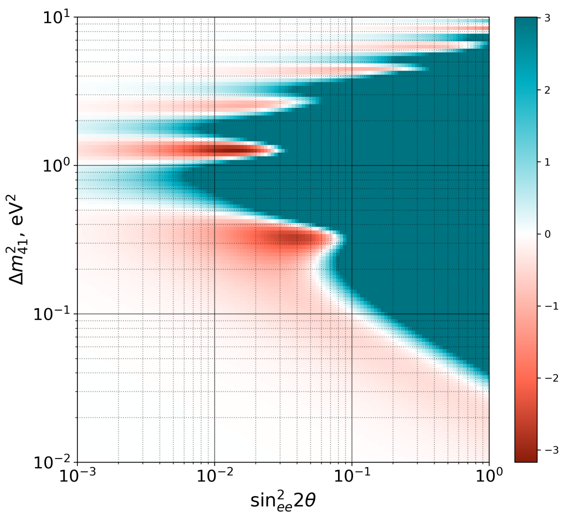

Figure 1: The χ^2 distribution for the 4ν hypothesis. **Preliminary**.

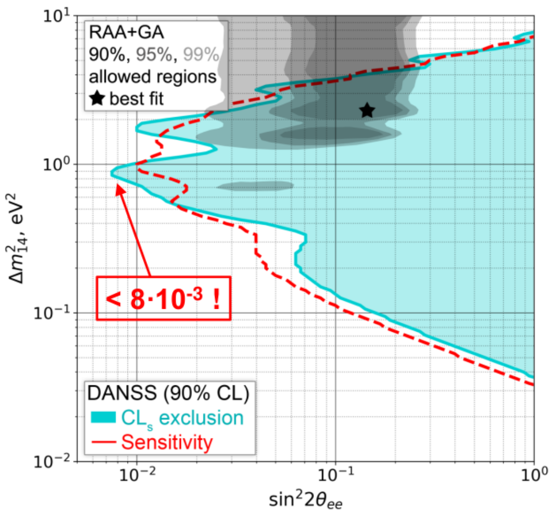

Figure 2: DANSS 4ν hypothesis 90% level exclusion region and sensitivity. Grey areas show allowed regions from [15]. **Preliminary**.

3. Tracing reactor power

DANSS was commissioned in April 2016 and since October 2016 a stable operation of the detector was maintained. Power of the reactor can be monitored by the IBD event rate. The reactor power observed during 4.5 years with an average statistical precision 1.9% in 2 days (1.5% in the position closest to the reactor core) is shown in fig. 3. Presented points include correction for the detector efficiency and the change in the fraction of fission isotopes during campaigns. No systematic deviation from the NPP power measurements is observed at the level better than 0.5%. A distribution of differences between the power measured by IBD rate and by standard reactor monitoring system normalized to corresponding statistical errors is presented in fig. 4. The distribution is centered at zero and its RMS is consistent with pure statistical nature of deviations.

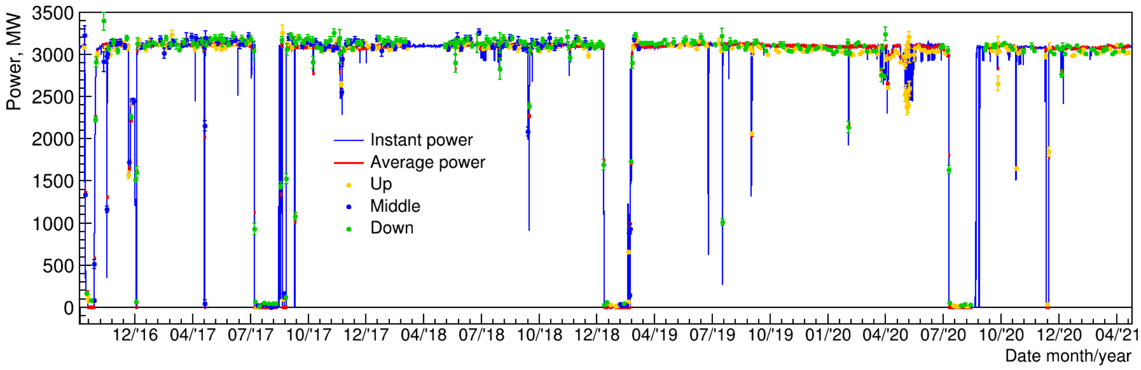

Figure 3: The reactor power measured by the neutrino counting rate corrected for the detector efficiency and the fuel evolution

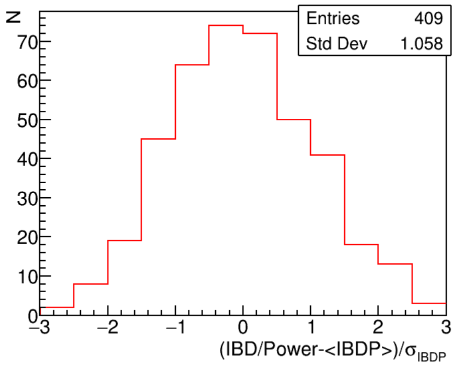

Figure 4: Differences between the reactor power calculated from the antineutrino flux and the power measured by the reactor controls.

4. DANSS upgrade

We plan the detector upgrade aimed to cure the most problematic feature of DANSS – its energy resolution. New polystyrene-based strips of size 1200x50x20 mm^3 with 8 wavelength shifting fibers in grooves were designed. A SiPM only readout from both sides of a strip will be used. The PMT readout will be abandoned and its space inside the passive shielding will be used to increase the sensitive volume. New strips were tested at a π-meson beam of PNPI accelerator. Longitudinal and transverse profiles are shown in fig. 5. Much better light yield and its uniformity were achieved compared to the old strips [16], so we can hope for 12% at 1 MeV energy resolution. Together with the 70% increase of the sensitive volume this will allow a significant improvement of the detector performance and an extension of the exclusion region in the direction of larger Δm^2_{41}, giving sensitivity in the region of the Neutrino-4 positive result ($\Delta m^2 \sim 7$ eV^2 and $\sin^2 2\theta \sim 0.35$) [7].

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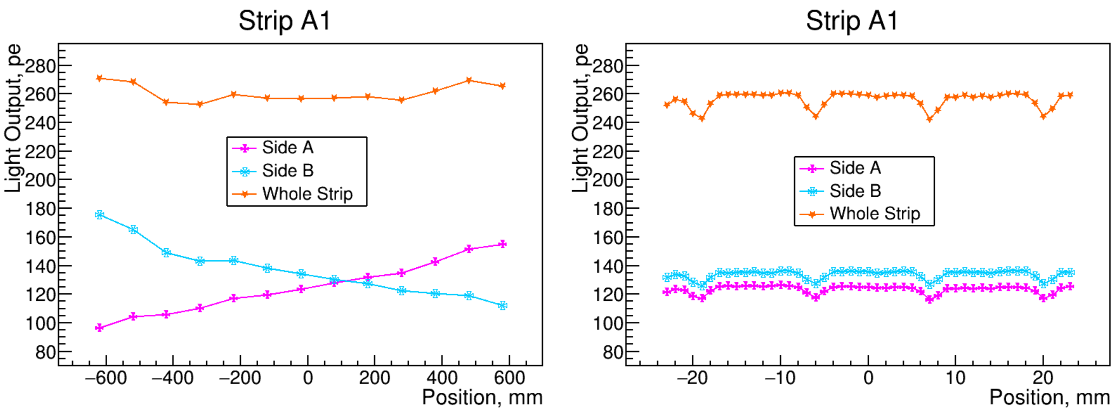

Figure 5: Transverse (left) and longitudinal (right) light yield profiles of the new strip in ph.e. obtained in the π-meson beam scan

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