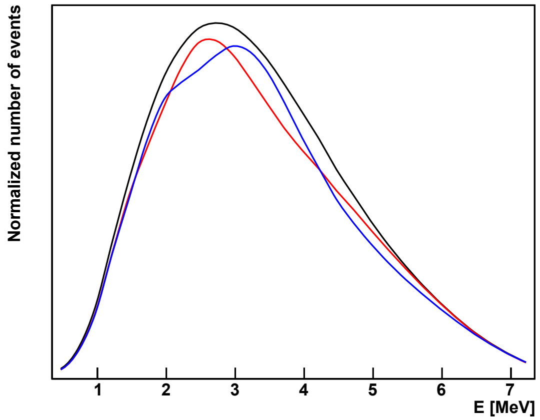

Expected energy-dependent rate without transition into sterile neutrinos (black) and with oscillations into sterile neutrinos for the cells nearest (red) and farthest (blue) to the reactor.

of the most likely sterile neutrino parameter ranges and try to discover the origin behind the reactor antineutrino anomaly.

Contributions of the MPIK

The neutrinos are detected in a Gd-loaded liquid scintillator, which is the heart of the STEREO detector. At MPIK we developed a novel Gd-loading technique in the context of the Double Chooz experiment. The chemical composition of this organic liquid was modified and optimized for the needs in the STEREO experiment. The background rate is lowered by a higher Gd concentration (0.2 wt.%) reducing the coincidence time of the neutrino signal. Furthermore, the scintillator design was tuned to increase pulse shape discrimination capabilities for further background reduction. As additional detector component, the institute is also responsible for the PMTs detecting the scintillation light. The 48 PMTs used in the STEREO detector were all tested and calibrated at MPIK. The tasks of the MPIK group are completed by a strong involvement in simulation studies and the analysis of experimental data, in particular in the areas of energy reconstruction, neutron detection efficiency studies and analysis coordination.

Title picture: View into the research reactor at the Institute Laue Langevin in Grenoble (© ILL/JL Baudet).

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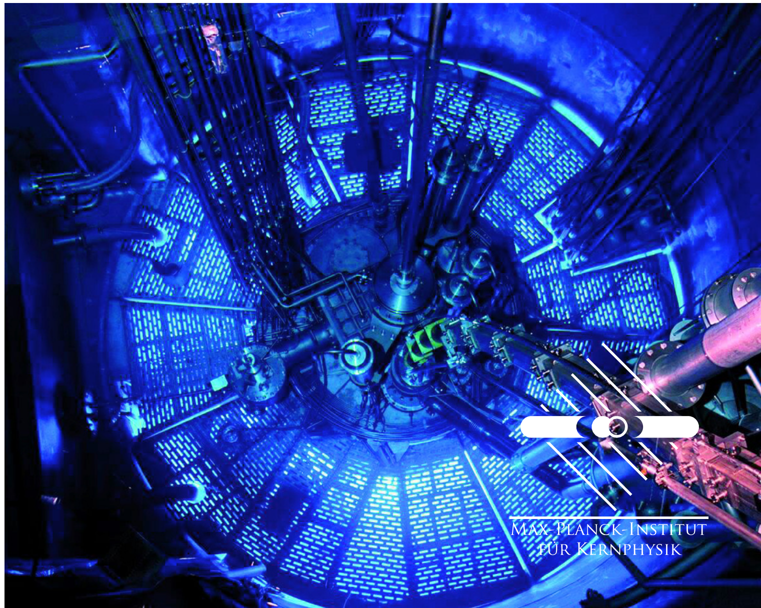
The Max-Planck-Institut für Kernphysik (MPIK) is one of 84 institutes and research establishments of the Max-Planck-Gesellschaft. The MPIK does basic experimental and theoretical research in the fields of Astroparticle Physics and Quantum Dynamics.

MAX-PLANCK-GESELLSCHAFT

STEREO

Are sterile neutrinos the explanation for the reactor antineutrino anomaly?



STEREO
Are sterile neutrinos the explanation for the reactor antineutrino anomaly?

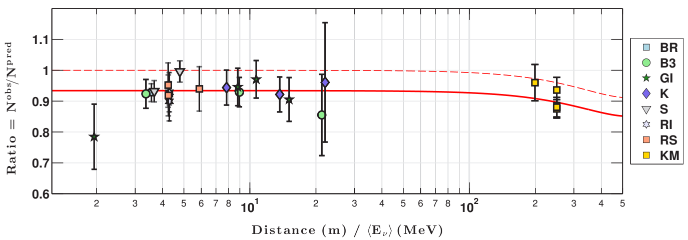
Nuclear reactors are strong neutrino sources. On the one hand, they can be used to study the fundamental properties of these elementary particles. On the other hand, the increasing knowledge on neutrino properties allows, by detecting neutrinos in the vicinity of a nuclear reactor, to obtain detailed information about the complex processes and decays happening in the interior of the reactor core. The STEREO experiment is expected to provide significant contributions in one way or the other. The primary goal of the experiment is to test the possible existence of sterile neutrinos. Their existence would manifest in an apparent disappearance of the original non-sterile neutrinos produced in the reactor core. The disappearance is caused by a conversion between the two types of neutrinos, which would be detectable in STEREO.

Neutrinos at nuclear reactors

There are three known types (flavors) of the elementary particle neutrino: electron neutrino, muon neutrino and tau neutrino. Each neutrino type is associated with an antineutrino. The radioactive decay of fission products in the nuclear reactor produces electron antineutrinos which are emitted isotropically in all directions. Due to the rather high production rate at a well localized source, nuclear reactors are well suited for neutrino experiments. A commercial nuclear power plant can produce more than sextillion neutrinos per second. Despite this huge number, the neutrino detection is challenging, since they hardly interact with matter and detectors in the ton scale are required. Neutrino experiments at nuclear reactors had a major impact on our current understanding of these particles. The first neutrino detection at all in 1956 was achieved by the reactor experiment of Nobel Laureates Reines and Cowan. Moreover, reactor neutrino experiments proved that neutrinos can change their flavor and transform from one type to another as they propagate. Evidence for such neutrino oscillations was for example observed in the Double Chooz experiment.

The reactor antineutrino anomaly

It has been observed that the neutrino flux measured in many experiments close to nuclear reactors (distance between detector and reactor <500 m) is significantly lower than the predicted flux rates (more than 6%). The probability that this is just a statistical fluctuation is less than 1%. This observation known as the reactor antineutrino anomaly might be due to transitions into sterile neutrinos. These sterile neutrinos cannot be detected by the experiments, which are only sensitive to electron antineutrinos. Other possibilities are also considered, such as possible biases in the flux prediction.

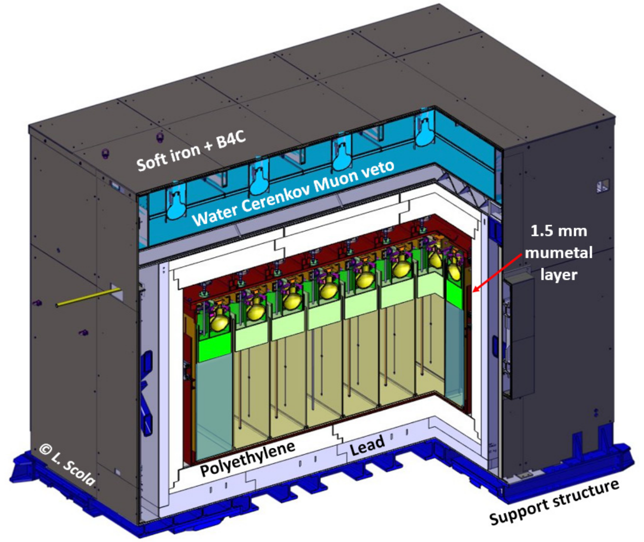


The ratio between the experimentally measured and predicted neutrino flux is 0,938 ± 0,024. The significance of a deviation from unity is 99,3% (2,7 sigma).

The STEREO experiment

The STEREO detector is positioned at a baseline of 10 m from a research reactor with 58 MW thermal power at the Institut Laue Langevin in Grenoble, France. The neutrino interaction occurs in 1800 liters of gadolinium (Gd) loaded liquid scintillator. The neutrinos are measured via the inverse beta decay on hydrogen nuclei (protons) inside the target liquid. In this reaction, a coincidence signal of a prompt positron and a delayed neutron capture on Gd is created in a coincidence time of several microseconds. Both events produce scintillation light, which is observed by a total of 48 photosensors (PMTs) on top of the detector. As shielding against cosmic radiation as well as radioactivity from the surrounding neutron scattering experiments, several layers of mainly lead and polyethylene are used with a total mass of about 65 tons. An additional detector above the neutrino detector is used to identify cosmic muons, which are one of the dominant sources of unwanted signals possibly mimicking a neutrino event.

The fiducial volume in the STEREO detector is divided into 6 identically designed cells, each of them at slightly different



The segmented STEREO detector and its shielding.

distance from the compact (40 cm diameter) reactor core, which is enriched in ^{235}U. Transformations into sterile neutrinos would yield in deformations of the neutrino energy spectrum. Due to the different baselines for each cell it would be expected that the observed deformations are in different energy regions of the measured neutrino spectra.

Data taking and results

After its installation in November 2016, the STEREO detector recorded data over 2 reactor cycles, for a total of 84 days, and 2 reactor-off periods, for a total of 32 days. This phase-I was followed by a long reactor shutdown of about 1 year devoted to reactor maintenance. In this period detector repairs were performed and the shielding was improved. The phase-II of the experiment started in October 2017 during a reactor-off period. STEREO aims for more than 300 days of reactor-on data before the end of 2019.

With the phase-I data only, already a significant part of the allowed region for the sterile neutrino parameters could be excluded. The best fit values of the reactor antineutrino anomaly could be excluded with a confidence level of 98.6%. With more data, the systematic and statistical uncertainties will further decrease and the sensitivity improve accordingly. With final statistics STEREO will test the main part