Analysis of the SoLiD experiment data: Measurement of the antineutrino spectrum at BR2 and search for oscillations towards a sterile neutrino.

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Scientific context:

The neutrino is one of the most enigmatic ingredient of the standard model of particle physics. Because of its weak interaction with matter and despite enormous experimental progress, its nature and its fundamental properties remain unknown: Dirac/Majorana, CP violation, absolute mass scale, other flavors… In addition neutrino becomes important messenger for several scientific domains such as non-proliferation in nuclear safety, geoneutrino, supernovae… For these reason, it is needed to continue new development in detection technique and to have a good characterization of neutrino behaviors. Recent results from the θ_{13} experiments have uncovered an intriguing excess of events detected in the 4-6 MeV reconstructed energy range with respect to predictions. This spectral distortion may be a suggestion of discrepancies within model of antineutrino production in reactors. Moreover, three independent experimental anomalies (reactor anomaly, Gallium and LSND/MiniBooNE) support the hypothesis of the existence of a new neutrino family called sterile because not interacting through weak interaction. In this context, new data from a precise pure ^{235}U Antineutrino spectrum are needed to resolve this open issue and to clarify the reactor anomaly.

To address this issue several experiments started to measure more precisely the neutrino spectrum close to a reactor (<10 m). In this context, SoLid has proposed to use a novel technology to measure antineutrino at the BR2 reactor at SCK-CEN (Mol, Belgique).

SoLid Experiment:

For all reactor experiments, the antineutrino detection is based on the inverse beta decay process (IBD). But the probability of interaction is extremely small. All new experiments will face to important experimental challenges. The problem is therefore the search for a low intensity neutrino signal within a very high environmental background.

The concept and technology of the SoLid set-up are innovative and answer to this need. This experiment use a solid state detector, based on two different scintillators (PVT, LiF:ZnS) and high segmentation. The use of ^{6}LiF:ZnS layers allows a distinct discrimination of the neutron signal. In addition, the segmentation allows to locate the antineutrino interactions and effectively reject significant background sources.

This project is performed by an international collaboration (France, UK, Belgium, USA), merging ten laboratories. Since the beginning, the LPC Caen is involved in this project by having contributions in the development and analysis of the first module SM1 as well as the simulation of the set-up with Geant4 and MCNP simulation (event generator, neutron efficiency). The local group take part of the reactor core simulation (fission map, acceptance and background neutrons). At last, the laboratory is in charged of the neutron calibration system, essential element of the set-up. During the construction, we have seen a good uniformity of the 12800 detection cells in term of neutron efficiency and energy calibration. Since spring 2018, the detector acquires data in physics mode.

Thesis topic:

The thesis topic proposed fully fits with the group activities. At a first step, we propose to develop a multi-dimensional analysis in order to distinguish background event from IBD event. This multivariate analysis will be applied in parallel on both data and simulations.

The second part of the thesis will focus on the exploitation of the antineutrino spectrum. A systematic comparison will be made with the different reactor spectra in order to constraint the ^{235}U

spectrum, in interaction with the reactor group of the SoLid collaborations, and a statistical analysis will be performed to test the sterile hypothesis.

The candidate must have computer skills (C++/Python programming), and statistical data analysis (root). He/She must be able to work in collaboration with people in the different laboratories. The candidate will acquire skills in neutrino physics, detection technique, simulations and data analysis.

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