SOX: Short distance neutrino Oscillations with BoreXino

Mid-Term Report Summary - SOX (SOX: Short distance neutrino Oscillations with BoreXino)

The SOX project is proceeding as expected.

Its main goal is the search of sterile neutrinos by means of a neutrino or an anti-neutrino source using the Borexino solar neutrino detector at Gran Sasso. By placing such a source close to the Borexino detector (distance from the center 8.5) SOX will perform a unique study of short distance neutrino oscillations which may prove the existence of sterile neutrinos or finally prove that they do not exist and that they cannot explain the so called reactor anomaly.

In the last 18 months we have faced and solved several issues and performed many activities. In particular:

The first problem addressed was to select the kind of neutrino or anti-neutrino source. Two options were originally considered in the proposal: a Cr-51 neutrino source and a Ce-144 anti-neutrino source.
source would be made by placing a large sample of Cr-50 into a nuclear reactor with a high neutron flux; the second is made by extracting Ce-144 from spent nuclear fuel.

After a careful set of studies made in collaboration with Oak Ridge National Laboratory in the USA, the Nucleco company in Italy, the experts of the CEA-Saclay in France, and the PA Mayak company in Russia, the Ce-144 antineutrino source has been preferred with respect to the Cr-51 neutrino source because it is easier to make technologically and more effective in terms of the final sterile neutrino source sensitivity. We may consider to perform a second Cr-51 neutrino run in the future, but the decision to make the Ce-144 experiment first is taken.

The Ce-144 will be made by about a liter of CeO2 powder which is obtained from spent nuclear fuel by means of a complex chemical process. The powder will be enclosed in a certified stainless steel double container and sealed according to international regulations. The stainless steel container is then encapsulated in a thick Tungsten shield which will stop most of gamma radiation produced by the power making the device relatively easy to use and safe from the radiological point of view.

The design of the source (CeO2 powder production, internal stainless steel capsule design, tungsten shielding) has been completed in strong and fruitful collaboration with CEA group (France) and the Russian PA Mayak company, which will build the source. The tender is in progress and the contract will be signed in a few weeks. All details of the source have been defined and designed. The technology for the production of the CeO2 powder are completely defined by PA Mayak company.

The tungsten shield, a key element for the biological shielding of the anti-neutrino source, has been designed as well in collaboration with CEA (France). It will be a cylindrical container with a minimum thickness of 19 cm made with two single pieces. Its purpose is the strong reduction of the gamma background produced by the nuclear decays of Ce-144, Pr-144 and other contaminants.

The tender was issued in spring 2015 and the order placed in September 2015. The winning company, Xiamen (China), is working to produce the piece, which is a one-of-a-kind fabrication: a cylindrical container 19cm thick minimum made of only two pieces, a base and a cap. The total weight is more than 2 tonnes and, as far as we know, such a piece has never been built so far.

Another key point of the experiment is the calorimetric measurement of the source activity. Being a neutrino disappearance experiment, SOX requires to know the total anti-neutrino flux produced by the source with a precision of 1% or better.

We have identified a suitable technology based on kevlar suspensions, standard cryogenic technologies, and vacuum systems which is expected to provide a calorimetric measurement of the 1 kW source with a heat loss of the order of a few W or less, exceeding the requirement of less than 1% necessary for the experiment (the lower the better but if the precision goes below 1% it does not help much because other systematic error dominates, such as the fiducial volume determination). This work has been done by SOX personnel hired on the grant and members of the SOX collaboration, particularly from Genova and TU Munich.

After 8 months long R/D and prototyping phase, we have completed the construction and precision testing and calibration with an electric mock-up source is now in progress. Preliminary results are very good and probably better than design goals.
We have defined in details the installation procedures of the source within the Hall C of the Laboratory Nazionali del Gran Sasso where Borexino is located. In particular, we have built a brand new insertion system based on small charts on rails which will allow to place the 2.8 ton source within the small tunnel that is located beneath the Borexino detector.

We have also finalised Monte Carlo simulations and completed sensitivity and optimisation studies. This work has been done by SOX personnel hired on the grant and members of the Borexino collaboration.

All these activities were foreseen in the original plan and are proceeding on schedule.

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