Borexino/DarkSide

Second phase of Borexino: solar neutrinos, geo-neutrinos, sterile neutrinos, dark matter

Borexino detector is the first liquid scintillation detector able to register sub-MeV neutrinos in real time. Borexino performed direct observations of ^{7}Be, pep, pp and ^{8}B solar neutrinos and proved the presence of transition region between vacuum and matter oscillations in the framework of the MSW/LMA solution of the solar neutrino problem. Other achievements of the collaboration to be mentioned are the first geo-neutrino observation, setting of the model-independent limits on low-energy antineutrino fluxes, confirmation of the absence of day-night variations and observation of seasonal variations of Solar ^{7}Be neutrino flux. The best limits on the effective magnetic moment of solar neutrinos and the electron lifetime with respect to the decay $e \rightarrow \nu\gamma$ were obtained. Within the multimessenger approach to astrophysical events, low-energy neutrinos in coincidence with gravitational waves and gamma-ray bursts have been searched for, and limits on the related neutrino fluxes are obtained.

The most important task for the second phase of Borexino remains the measurement (or reasonable bounding) of the CNO-neutrino flux. The predictions for this flux differs by up to 30-40% for two classes of solar models, thus measurement of the CNO flux with moderate precision will help to solve the ambiguity. The key point of the analysis is the achievement of the low count of ^{210}Po in order to obtain a supporting term from the parent ^{210}Bi, which is the major residual background mimicking the CNO spectrum. During the first phase and the beginning of the second phase of the experiment, we observed significant fluctuations of ^{210}Po count rate due to convective flows in the scintillation volume. It was therefore decided to insulate the detector with aim of the suppression of convective movement bringing ^{210}Po from the inner nylon vessel to the fiducial volume. In the absence of convective movement only the contribution of ^{210}Po in seqular equilibrium with its parent ^{210}Bi is expected to remain in the inner volume. With an ample period of data taking in these stable conditions the support level of ^{210}Po should be measured rather precisely, providing the sought constraint on the ^{210}Bi and, therefore, in turn to the evaluation of the CNO through the global solar fit in which such a constraint would be exploited. Mechanical works on the detector's insulation have been accomplished in 2015, later an active thermostabilization system has been added at the top of the detector. By the end of 2017 the temperature in the detector has stabilized. Temperature control is conducted with a system of temperature sensors mounted in different parts of the inner volume. As a result of temperature stabilization, event rate of ^{210}Po has also stabilized, making the task of measuring the CNO neutrino flux feasible.

Precision of the pp-neutrino flux measurement can still be improved by including the Phase-I data in the analysis. Up to now the analysis of the lowest-energy part of the Phase-I data has not been provided due to the chosen previously approach to the data selection: one of the selection methods (namely, “soft” alpha-beta discrimination) distorted the spectrum at low energies, therefore the selected threshold for the analysis was higher than end-point energy of recoil electrons for the pp-neutrino spectrum. Our group has developed an approach without the suppression of alpha-particles contribution which was successfully applied to the Phase-II data analysis. Taking into account better energy resolution at the beginning of the detector operation we expect an improvement in the precision of the pp-neutrino flux measurement of up to 6-7% by including the Phase-I data in the analysis.

Another important task for the second phase of the experiment is an improvement of geo-neutrino flux measurement. It is proposed to reject the spatial event selection (it would practically double the available statistics) and to improve the selection of events correlated with cosmic muons (at the moment a simple muon veto is used leading to about 10% loss of statistics). As a result of the absence of spatial selection, a contribution from the external background appears in the observed anti-neutrino spectrum. Work on the understanding of the source of this background and adding its shape in the spectral analysis is included in the working plan for the near future.

Moreover, Borexino data will be used for investigation of non-standard contributions to neutrino interactions by deviation of the recoil electrons spectral shape from the Standard Model prediction.

In Borexino, we are planning to perform measurements with ^{144}Ce-based anti-neutrino source located beneath the detector (CeSOX program). The source of about 100 kCi activity will be produced at the Mayak plant by April 2018. Hardware preparations for the source accommodation in the outer tunnel under the detector and calorimetry measurements are completed. Besides this, biological tungsten shielding is manufactured. The collaboration is ready for the data analysis and processing directly after the start of data taking.

Concerning the dark matter investigations, our group participates in the DarkSide collaboration, the start of the activities was triggered by our involment in the CTF (the prototype of the Borexino used as a host for the DS50) operations. The DarkSide prototype detector (DarkSide-50 or DS-50) is successfully taking data since November 2013. Design of the full scale 20-ton detector (DS20k) is now at the stage of detailed study, the project and the physical program of the investigations (Yellow book) is published. Due to the multi-ton scale of the underground argon target the expected sensitivity to WIMP-nucleon cross section is at the level of 10^{-47} cm^2 for several years of data taking.

Significant progress is achieved in the whole low activity argon (LRAr) production chain, either within Urania (sub-project for underground argon extraction) and Aria (sub-project for isotope separation) activities.

In April 2015 the DS-50 cryostat was filled with 153 kg of underground argon (UAr), the first result was the measurement of abundance of radioactive ^{39}Ar which appeared to be 200 times less than in the atmospheric argon (AAr). In the dark matter search mode the exposure of (2616±43 kg·d) allowed to obtain a limit on the spin-independent WIMP-nucleon interaction cross section of $2.0 \cdot 10^{-44}$ cm^2 for WIMPs of mass 100 GeV. Nowadays the DS-50 detector continues data taking, acquired exposure corresponds to 650 days livelime, data is now being processed for blind analysis.

The group from JINR, having gained an expertise with low-background Borexino detector, is planning to take a part in the data analysis of the second stage of the experiment, especially in geo-neutrino measurements, improvement of the pp-neutrino flux measurement, as well as in new studies with anti-neutrino source in the framework of the SOX project. In DarkSide, we are planning to participate in data analysis aiming at precise experimental measurement of the

^{39}Ar spectral shape and improvement of the analytical energy scale description. The group will also participate in the Monte Carlo modeling of DS20k components, in particular SiPM modeling, simulation of radiation neutron capture at different parts of the structure in order to choose the optimal configuration from the point of view of minimizing the backgrounds. We also participate in studies of detector's sensitivity to supernova neutrinos.

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