Borexino experiment

1. Goals of the experiment:

Primary goal of the experiment was a measurement of the solar neutrino emitted in ^{7}Be-reaction in the Sun with a precision of 5%. The goal was successfully accomplished at 2010, later the precision of the measurement was further improved, 2.7% precision was reported in a recent publication in Nature journal.

The unprecedented level of the liquid scintillator (LS) radiopurity achieved in experiment allowed to extend the initial program, performing studies of other Solar neutrino fluxes, the first confirmation of the geoneutrino existence, a number of studies on the non-standard neutrino properties, etc.

The sensitivity of the detector allows the Borexino collaboration to challenge the CNO-neutrino flux measurement, which is considered as the main goal on the actual stage of the experiment. With the purpose of the CNO-neutrino flux measurement, the thermal insulation of the detector has been performed to stabilize the backgrounds. Another feasible measurement of high importance will be an improvement of the precision of the pp-neutrino flux measurement up to the level of 7-8%.

The measurement of the CNO neutrino flux with moderate precision will allow to solve the Solar metallicity puzzle.

1b. Explain what the project adds to the international scenario:

Borexino is a unique experiment with record radiopurity of the liquid scintillator. For the moment it is the only one sensitive to the solar neutrino in the sub-MeV region.

2. Contributions of the JINR group:

2a.

- Data acquisition system for the prototype detector (CTF)
- Preparation of the PMT test facility and tests of 2200 PMTs for the experiment.
- Development of the automated system for controlled setting of the PMT HV
- Tests of the mu-metal magnetic shielding for the CTF and Borexino
- Development of the PMT charge and timing calibration techniques
- CTF data analysis for 8 scientific papers on the search of possible manifestation of the non-standard physics
- Participation in the Borexino cabling; PMT cleaning
- Data taking shifts during the CTF campaign and the whole Borexino data taking period
- Software: radon monitor developed
- Development of the analytical model for the description of the energy scale, energy resolution and the shape of the detector response; promotion of the use of new energy estimators
- Software: algorithms for the standard analytical fitter
- Data analysis for the 7Be and pp- Solar neutrino fluxes; for the geo-neutrino studies; for the paper on neutrino magnetic moment limits; for the "electron decay" paper
- Porting the analysis software (fitter) to the GPU-based systems

2b.

O.Smirnov – IB member of Borexino.

O.Smirnov – from 2018 leader of the "Phase I and Phase II joint analysis" working group; in 2012-2014 headed the "pp analysis" WG (Borexino).

O.Smirnov – in various periods: a member of the Steering Committee (Borexino).

3. Plans

- Prepare a paper on the limits on the non-standard neutrino interactions
- Joint analysis of the Phase I and Phase II data with a goal of 7-8% for the pp-neutrino flux measurement.
- Improvement of the limits obtained with Phase II adding earlier data.
- Take part in the CNO analysis
- Take part in the geo-neutrino analysis of the extended set of data

4. Publications:

1. M. Agostini et al. (The Borexino collaboration), "Limiting neutrino magnetic moments with Borexino Phase-II solar neutrino data", Phys.Rev.D 96, 091103(R) (2017); **Data analysis (100%), text (100%), correspondence**
2. M. Agostini et al. (The Borexino collaboration), "Seasonal Modulation of the 7Be Solar Neutrino Rate in Borexino", Astroparticle Physics Volume 92, June 2017, Pages 21–29. **Internal review**
3. M. Agostini et al. (The Borexino collaboration, "Comprehensive measurement of pp-chain solar neutrinos", Nature, vol.562, pages 505–510 (2018). **Data analysis (energy scale tuning, pile-up simulation, 7Be and pp-neutrino part, multivariate fit), contribution to writing, internal review**

Total number of papers by collaboration on 2016-2018 is 6 (Borexino).

5. PhD theses:

- A.Vishneva, "Testing the electric charge conservation and limiting the effective neutrino magnetic moment using the Borexino data" (in preparation for 2019)
- A.Formozov, "Search for the non-standard neutrino interactions with Borexino data" (ready to be defended at the beginning of 2019)

6. Talks:

Plenary talks:

1. O.Smirnov, "Borexino. Recent results and future plans", Международная сессия-конференция Секции ядерной физики ОФН РАН "Физика фундаментальных взаимодействий", ОИЯИ, Дубна. 12 -17 апреля 2016 г.
2. O.Smirnov on behalf of the Borexino collaboration. "Geoneutrino flux measurement with Borexino detector", International Workshop: Neutrino Research and Thermal Evolution of the Earth, October 25 – 27, 2016, Sendai, Japan
3. O.Smirnov on behalf of the Borexino collaboration, "Limits on the neutrino magnetic moments", Recent development in Neutrino Physics and Astrophysics LNGS, September 4-7, 2017.
4. O.Smirnov on behalf of the Borexino collaboration, "Borexino", The Mount Elbrus Conference from Deep Underground up to the Sky, Pyatigorsk, September 11-15, 2017.

5. O.Smirnov, "Geo-neutrino : experimental status and perspectives", Conference on Neutrino and Nuclear Physics (CNNP2017) 15-21 October 2017, Monastero dei Benedettini, University of Catania, Catania, Italy.
6. O.Smirnov, on behalf of the Borexino collab., "Experimental limits on neutrino magnetic moments (Borexino results)", Solvay workshop on "Beyond the Standard model with Neutrinos and Nuclear physics", Brussels, November 29-December 1, 2017.
7. O.Smirnov, on behalf of the Borexino collab., "Solar neutrino from pp-chain and other results of Borexino", XXVIII International Conference on Neutrino Physics and Astrophysics, Heidelberg, June 5, 2018.
8. A.Vishneva (on behalf of Borexino collaboration), "Limits on neutrino magnetic moments from the spectral analysis of the Borexino Phase-II data", 5th international solar neutrino conference, June 11-15, Dresden, Germany

6b. Parallel talks.

1. A.Vishneva (on behalf of Borexino collaboration), "New limit on the electron lifetime in the Borexino experiment", AYSS-2016, 14-18 March, 2016, Dubna, Russia
2. A.Vishneva (on behalf of Borexino collaboration), "Status of the SOX project", ICPPA-2016, 10-14 October, 2016, Moscow, Russia
3. O.Smirnov, "Measurement of the geo-neutrino fluxes: status and future", International Session-Conference of the Section of Nuclear Physics of the Physical Sciences Department of the Russian Academy of Sciences "Physics of fundamental interactions" dedicated to 50th anniversary of Baksan Neutrino Observatory, June 6-8, 2017.
4. A.Vishneva (on behalf of Borexino collaboration), "Recent results of Borexino", Session-Conference SNP PSD RAS, 6-8 June 2017, Nalchik, Russia
5. A. Vishneva (on behalf of Borexino collaboration), "Effective neutrino magnetic moment limit from Borexino data", AYSS-2018, 23-27 April, 2018, Dubna, Russia
6. A. Vishneva (on behalf of Borexino collaboration), "New constraints on magnetic moments of solar neutrinos in Borexino", ICPPA-2018, 22-26 October, 2018, Moscow, Russia

7. Group size, composition and budget.

7a.

The JINR group involvement in the project is presented in Table. Total number of people involved in the Borexino project ~100.

Name	Position	Responsibilities	FTE
Smirnov O.Yu.	Senior Researcher	Administrative tasks, R&D, data analysis (Borexino)	0.75

Fomenko K.A.	Researcher	MC/Geant4 (Borexino)	0.5
Formozov A.A.	PhD student	R&D, data analysis (Borexino)	0.5
Sotnikov A.P.	Engineer	hardware, electronics, PMT tests (Borexino)	0.4
Vishneva A.V.	Engineer	data analysis (Borexino)	1.0
Gromov M.B.	Researcher	data analysis (Borexino)	0.5

Table 1　JINR group human resources, FTE is for Full time equivalent. Total FTE=3.65

7b. K.Fomenko left the group in 2018; Formozov will defend a PhD in 2019 and will change the field of research; M.Gromov joined in 2018. Looking for PhD students.

7c. Group budget for 2018: $19000 travels + $5000 resources

7d. There are plans to use JINR computing resources for the data storage and analysis.