Search for Low-Energy Signals from Fast Radio Bursts with the Borexino Detector

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The search for neutrino events in correlation with 42 most intense fast radio bursts (FRBs) has been performed using the Borexino dataset from 05/2007 to 06/2021. We have searched for signals with visible energies above 250 keV within a time window of ±1000 s corresponding to detection time of a particular FRB. We also applied an alternative approach based on searching for specific shapes of neutrino-electron scattering spectra in the full exposure data of the Borexino detector [1].

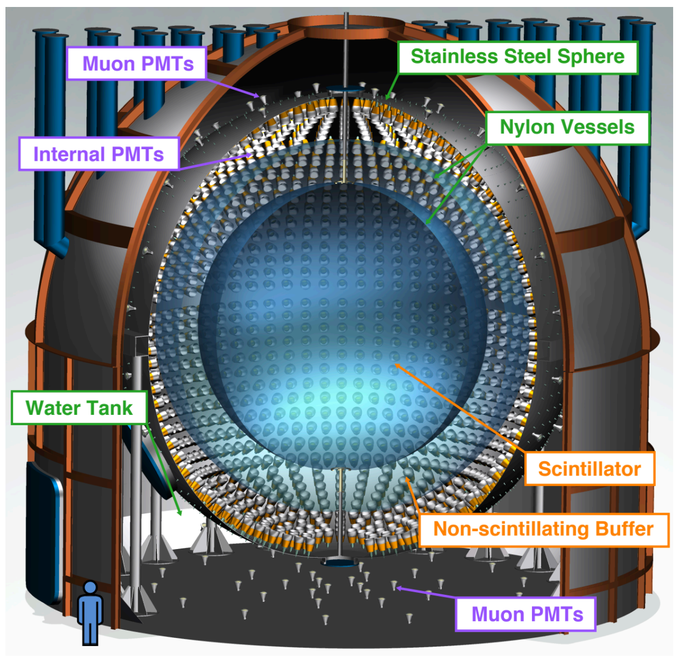
Introduction

A promising way of studying properties of distant objects and transient sources in the Universe is exploring neutrino coming from that sources. Such transients as Fast Radio Bursts (FRB) are of particular interest for astroparticle physics. FRB is a millisecond radio transient observed at extragalactic or cosmological distance. Numerous models with a wide variety of physical processes have been proposed to explain the origin of FRBs. Some of these models predict an low-energy neutrino emission from FRB.

The most sensitive tool for studying neutrino with energies in the region 250 keV - 5 MeV is the Borexino detector, a unique 300 t mass low-background scintillator detector operated in the Gran Sasso Laboratory.

Borexino detector

Detector located in the Gran Sasso Laboratory

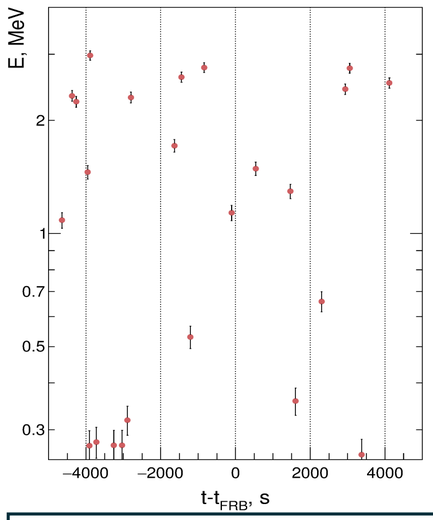


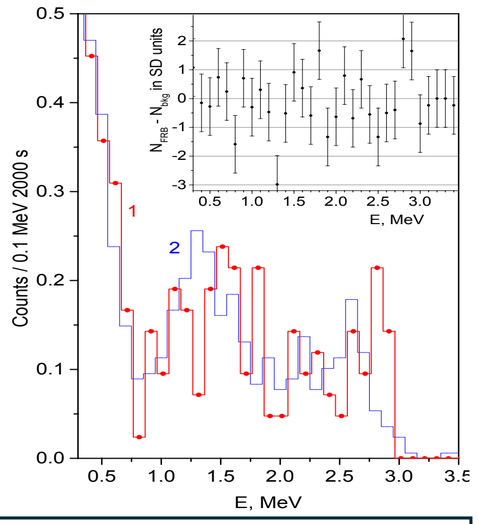
Water tank:
2.1 kt of water
Radiation shielding
Muon veto
Stainless Steel Sphere:
R = 6.85 m
Sustaining structure + scintillator volume
Nylon vessel (OV – outer, IV – inner):
(OV) R = 5.5 m, barrier for Rn from steel
(IV) R = 4.25 m, filled by ~300 t of liquid organic scintillator (pseudocumene/PPO)
Muon PMT's: 208 8"
Internal PMT's: 2212 8"

Neutrino registration method: Elastic scattering on electrons
Construction benefits: high light yield (~500 p.e./MeV)
High radio purity: < 5 10^{-9} Bq/kg (on ^{238}U isotope)

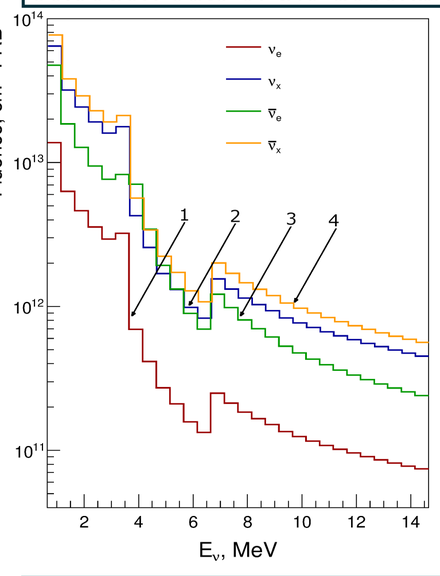
Data analysis and result

Temporal correlations for the most intensive FRBs



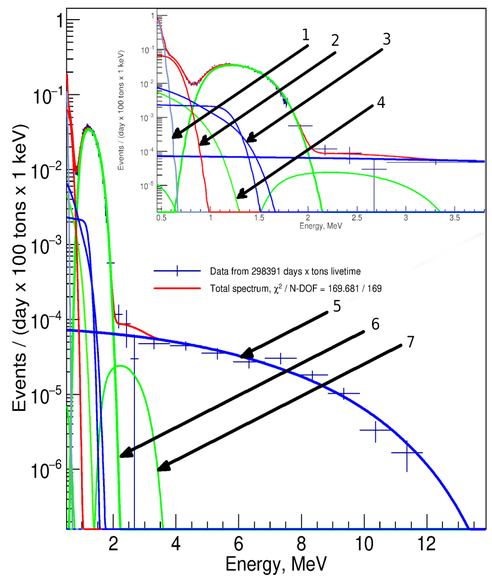


The goal of this analysis was to search for an excess of the selected events above the measured background, in coincidence with FRBs in a time window of $\Delta t = 2000$ s centered at the FRB arrival time.
We calculated the overall number of candidate events above 250 keV in the Δt interval, which met the requirements for selection cuts of the described data.

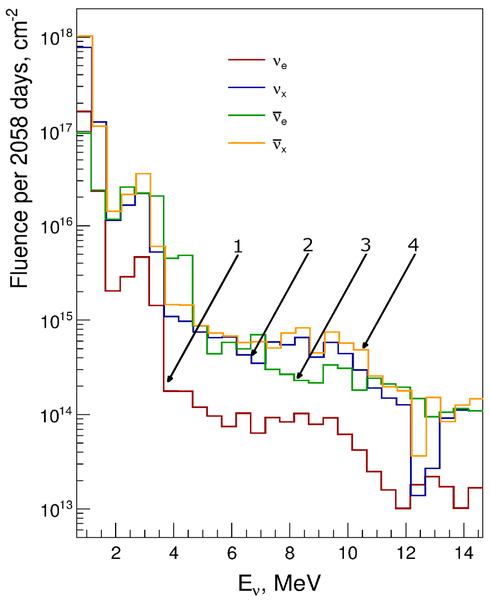


90% C.L. upper limits on mono-energetic neutrino fluences obtained through the temporal correlation analysis for 42 most intensive FRBs with the fluence $\Phi_{\mathrm{FRB}} \geq 40$ Jy ms: 1 – ν_e, 2 – $\nu_{\mu,\tau}$, 3 – $\bar{\nu}_e$, 4 – $\bar{\nu}_{\mu,\tau}$.

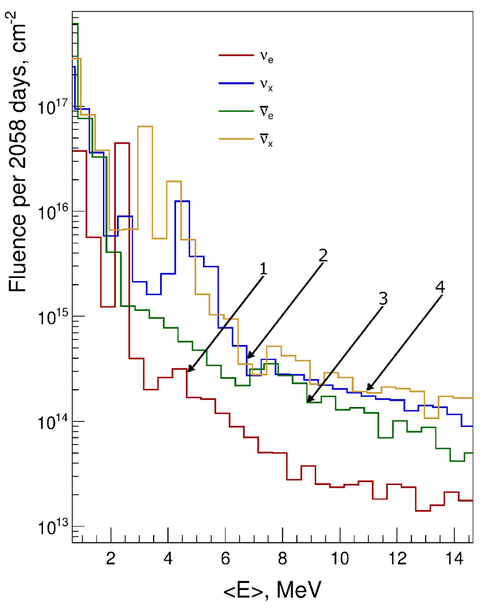
Limits on the $\nu_{e,\mu,\tau}$ and $\bar{\nu}_{e,\mu,\tau}$ fluences from the spectral fit



Spectral fit of the selected Borexino data after statistical subtraction of external backgrounds. The spectral components considered are: 1 – ^{210}Po α-peak, 2 – recoiled electrons from the solar ^{7}Be, 3 – recoiled electrons from the solar CNO and pep-neutrinos, 4 – ^{210}Bi β-spectrum, 5 – solar ^{8}B neutrino electron recoils, 6 – ^{11}C β^+-decay, 7 – ^{10}C β^+-decay. The inset shows the data in the energy range 0.5—4 MeV.



Upper limits on the fluences of monoenergetic $\nu_{e,\mu,\tau}$ and $\bar{\nu}_{e,\mu,\tau}$ obtained from the spectral fit (90%C.L.): 1 – ν_e, 2 – $\nu_{\mu,\tau}$, 3 – $\bar{\nu}_e$, 4 – $\bar{\nu}_{\mu,\tau}$



Upper limits on the fluences of $\nu_{e,\mu,\tau}$ and $\bar{\nu}_{e,\mu,\tau}$ with supernova neutrino spectra obtained from the spectral fit (90%C.L.): 1 – ν_e, 2 – $\nu_{\mu,\tau}$, 3 – $\bar{\nu}_e$, 4 – $\bar{\nu}_{\mu,\tau}$

Figure of spectral fit shows the Borexino spectrum in the range 0.5 - 14 MeV after applying data selection cuts for 298.39 kt day statistics or 2058 days of live time. The background used in the fit procedure was described with the actual spectral components, such as ^{210}Po, ^{85}Kr, solar neutrino recoil electrons, ^{11}C, and ^{10}C.
External gammas were statistically subtracted and thus were not included in the fit that was performed with the standard χ^2 likelihood function.

The additional component responsible for the potential FRB signal was added to the background and had a spectral shape of the monoenergetic line with the energy E_ν or the supernova spectrum with different $\langle E \rangle$ values.

Taking into account the number of FRBs expected in 2058 days, the obtained limit turns out to be 9×10^3 times more stringent than the one obtained from the temporal analysis

References

1. Appel, S. and others (BOREXINO collaboration), Search for low-energy signals from fast radio bursts with the Borexino detector // Eur. Phys. J. C. 2022. V. 82. N. 3. P. 278. doi: 10.1140/epjc/s10052-022-10197-0

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Conclusion

We looked for an excess in the number of events detected by Borexino produced by neutrino-electron elastic scattering and the inverse beta-decay correlated to the most intense FRBs between 2007 and 2021.
We found **no statistically significant** increase in the number of events, with the visible energy above 0.25~MeV within time windows of ±1000 s centred at the time of FRB arrivals.

As a result, new limits on the fluence of monochromatic neutrinos and supernova neutrinos of all flavors were set for neutrino energies in the range of 0.5 - 15 MeV.