The search for coincidences of rare events using LVD and BUST detectors

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Abstract The results of the time coincidences of rare events in the LVD and BUST detectors are presented. The rare events could be caused by neutrino interaction in the experimental setup. The distributions of the coincidence number per day for 4-year period are obtained.

Keywords: Underground Physics, Neutrino, Supernovae

1. Introduction

Correct background estimations are very important in the underground physics experiments. The main goal of the experiments is the search for neutrino bursts from collapsing stars, double beta-decay, proton decay, dark matter particles and other extremely rare phenomena. Within the work, research of extremely rare events coincidence will enable us estimating parameters of the search for neutrino bursts. The work is based on data of two experimental large underground detectors: Large Volume Detector (LVD) and Baksan Underground Scintillation Telescope (BUST). The detectors have been operating during the same time since 1992 and because they are situated in different places the background value of pulse coincidences for these detectors is much lower than for each one. Search for event coincidences between LVD and BUST within one second time interval are provided.

2. SN1987A and understanding problems of experimental results

Neutrino bursts from Supernova SN1987A were detected on February 23, 1987. The supernova SN1987A exploded in the Large Magellanic Cloud at a distance of ~50 kpc from the Earth [1]. Four underground detectors (LSD, BUST, Kamiokande, and IMB) were operating at that time and recorded two bursts of neutrino emission at 02:52 and at 07:35 UT [2]. According to standard stellar collapse models developed before the SN1987A phenomenon, the stellar collapse should be accompanied by one neutrino burst. In Figure 1 the time diagram of registered events is presented.

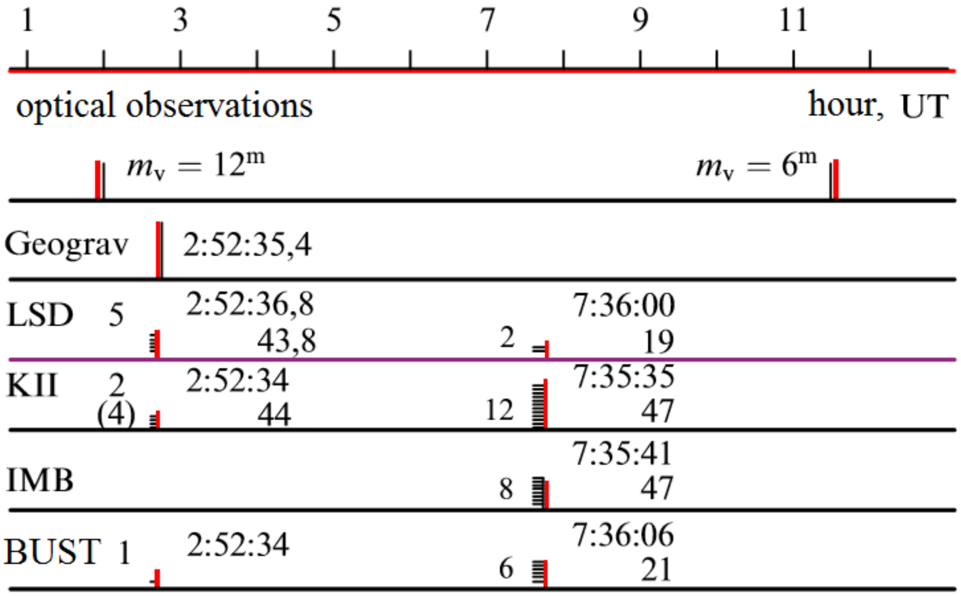


Fig1. *Timing diagram of registered events from SN 1987A.*

As is shown in the diagram, near 02:52 UT, the most number of events were observed by LSD detector. After that, the search for coincidences in the one-second time window between the single pulses of different pairs of detectors was carried out. The results presented in Figure 2.

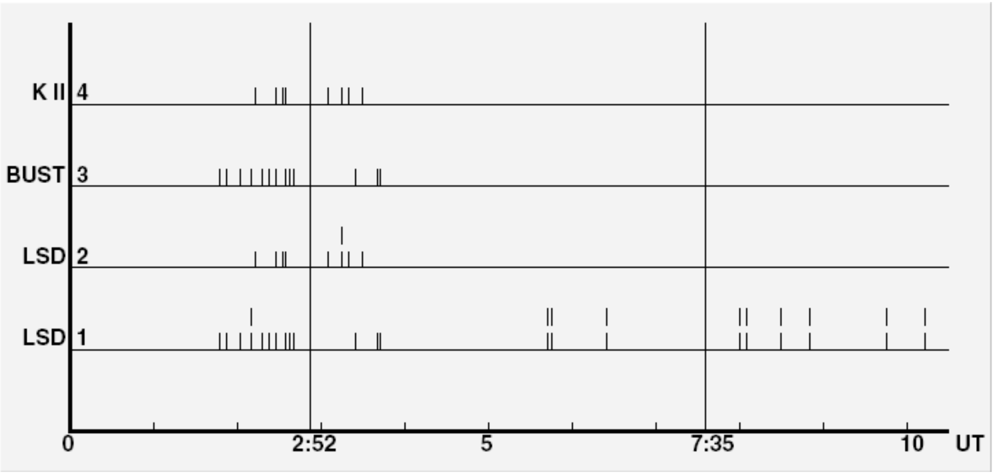


Fig2. *The timing diagram of coincidences of the BUST and LSD pulses within 1 s and similar coincidences for the K2 and LSD detectors as well as double pulses in LSD over the period from 0:00 to 10:00 UT on February 23, 1987.*

As a result, a statistically significant increase was found in the number of matches between single pulses in the LSD [3] and BUST [4] detectors and in the LSD and Kamiokande detectors around 02:52 UT [5]. Near the 07:35 UT 12 signals were registered by Kamiokande detector, 8 events - by IMB detector, 6 events - by BUST detector and 2 events - by LSD detector. The event detecting principle by the experimental facilities is based on different physical phenomena: the IMB and Kamiokande registration is based on Cherenkov radiation, LSD and BUST are scintillation detectors. Moreover, only the LSD detector could observe and define all types of neutrinos and antineutrinos, mainly electron neutrinos and antineutrinos. For resolving all problems associated with the understanding of experimental results it is necessary to get answers to some questions. Was neutrino burst detected at 2:52 UT 23, February, 1987? What was type of neutrino detected? How to explain the number of coincidences between single pulses obtained from different detectors pairs? Is the background the number of coincidences? For estimating the background level from single pulses coincidences, searching for coincidences between LVD and BUST events within one second time interval are provided. In the work, the data from 2011 to 2014 were analyzed.

Other objective difficulties of the experimental data processing during the neutrino bursts from SN1987A should be taken into account. In particular, processing of experimental data with two detectors covering a long period of time (about a year) was an almost impossible task because there was no modern computing power. At present time, the joint analysis of data from two different experiments does not look complicated. Moreover, the BUST detector registered neutrino burst from SN1987A and the LSD detector are a prototype of the LVD detector. Search for coincidences of single pulses between the LVD and BUST detectors allows us reconsidering the similar results obtained during SN1987A. In the case of a low counting rate of double coincidences, the experimental results of SN1987A become important.

3. LVD and BUST experiments

Sensitivity of LVD [6] is ten times higher than that of its prototype – the Liquid Scintillator Detector (LSD), which observed five pulses over seven seconds on February 23, 1987 at 02:52 UT (Fig.1). It is located at the LNGS underground laboratory (the Laboratori Nazionali del Gran Sasso, Italy) at a depth of 3650 m.w.e. The LVD detector is an underground iron-scintillator calorimeter with a total mass of 2 kt (1 kt of liquid scintillator and 1 kt of iron). The detector contains 840 independent scintillation counters. Structure of the LVD detector is presented in Fig.3. The structure includes 3 towers. Each tower contains 5 columns, each column consists of 7 portatank levels. Each portatank consists of 8 counters. The modular structure of the LVD and BUST detectors allows us using external counters as an active protection against muons and other background events.

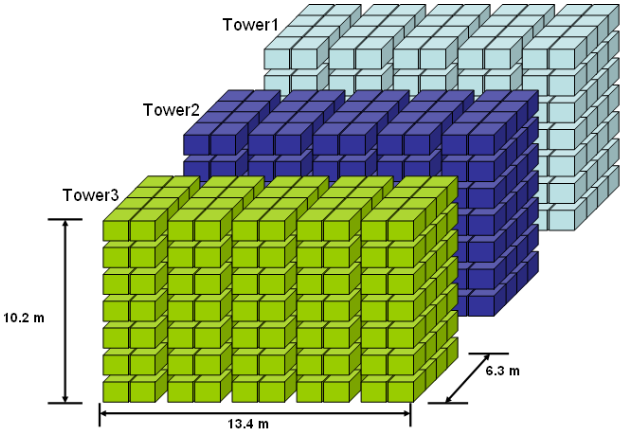


Fig3. *Modular structure of the LVD detector.*

The BUST detector [4] is located in the North Caucasus, under the mountain Andyrchy at an effective depth of 850 m.w.e. Its size is 17 × 17 × 11 m^3 and it consists of four horizontal and four vertical plates with scintillation counters. Five plates are external, while the three lowers of horizontal planes are internal (Fig. 4). The counter size is 0.7 × 0.7 × 0.3 m^3. The total number of counters is 3184 and the total scintillator mass is about 0.3 kt. The internal volumes of the counters are filled with liquid scintillator and viewed by the PMT 49B. The operating threshold of the counter is 8 MeV. Identical white spirit based scintillator is used both in LVD and in BUST detectors. In addition to its extremely low cost, the parameters of this scintillator remain virtually stationary under operating conditions during long time [1, 7].

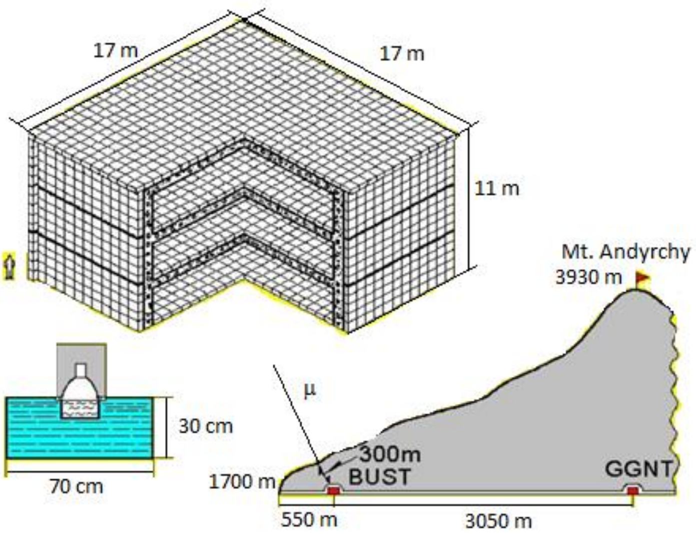


Fig4. *Scheme of the BUST detector.*

4. Obtained results

In the work, only “neutrino” events in the LVD and BUST detectors are used in analysis. The “neutrino” event is a response of only one inner counter, so far as external counters are used for active defense. The search for coincidences between LVD and BUST “neutrino” events within 1 second time interval was carried out with the 10 MeV energy threshold. The search results allow us to conclude about background origin of found coincidences, i.e., coincidences can be random. Indeed, when looking at the energy spectra of events in LVD and events in BUST, it is possible to see a difference between their forms. In the case of the same origin of “neutrino” events in LVD and BUST their energy spectrum would be identical also. However, in presented energy distributions for 2011-2014 years this is not observed, as is seen in Figs. 5-6. Moreover, the form of the spectrum in LVD and BUST remains constant, indicating different origins of the backgrounds in the experiments.

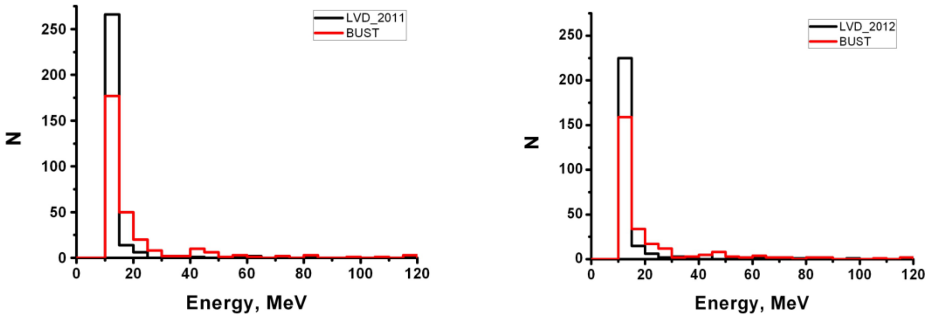


Fig. 5. *The energy spectra of events in coincidences for 2011 year (left) and 2012 year (right).*

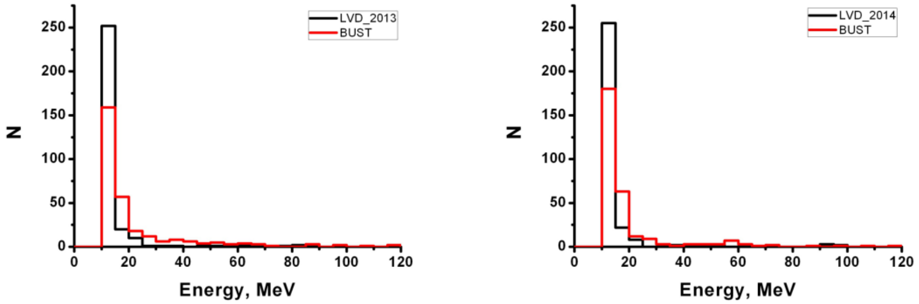
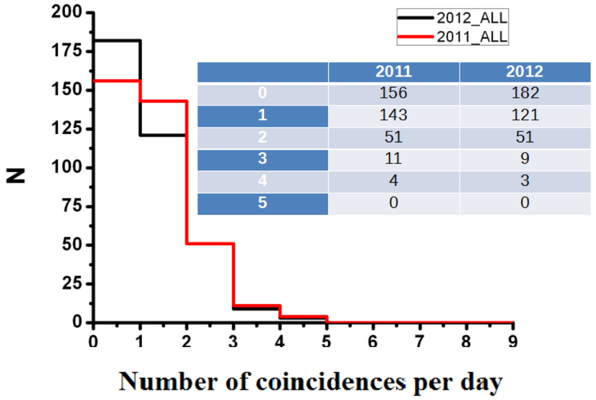


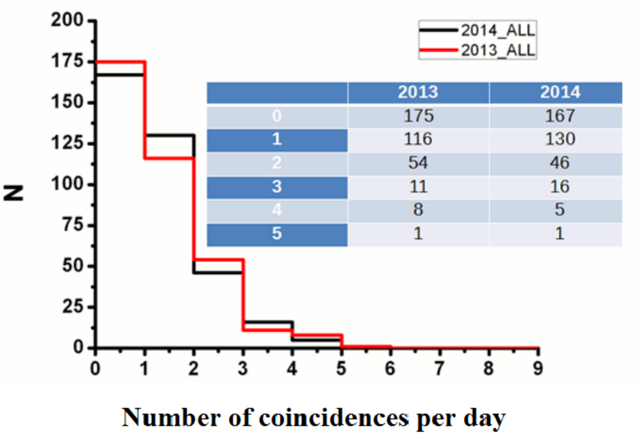
Fig6. *The energy spectra of events in coincidences during 2013 (left) and 2014 (right).*

To assess the average counting rate the distribution number of coincidences per day were built. Below the data for 2011-2014 are presented. As can be seen from the presented distributions, 5 coincidences per day were recorded only twice during 4 years of readout experimental data. This fact supports the importance of experimental results of SN1987A (see Fig. 2), when 13 coincidences were observed during 2 hours. On average, the counting rate of random coincidences is approximately 1 coincidence per day. The obtained results are presented in Figs. 7-8.



	2011	2012
0	156	182
1	143	121
2	51	51
3	11	9
4	4	3
5	0	0

Fig7. *The spectra of number of coincidences per day for 2011-2012.*



	2013	2014
0	175	167
1	116	130
2	54	46
3	11	16
4	8	5
5	1	1

Fig8. *The spectra of number of coincidences per day for 2013-2014.*

5. Conclusion

The results of neutrino event coincidences registered in the LVD and BUST detectors during 1 second allow us making the following inferences. The counting rate coincidences remained practically unchanged during 4 years of experimental data set, which indicates the stable work of the experiments. In the future, it is planning to carry out the search for coincidences during the whole period of joint work of detectors, i.e. since 1992. Different forms of the energy spectra allow us making a conclusion about different sources of background in the experiments.

The experimental value of the counting rate obtained in the present work demonstrates the importance of experimental results on SN1987A of 23 February 1987. The greatest value of the counting rate of accidental coincidences per day was recorded only 2 times in 4 years and is 5 matches a day. On 23 February 1987 (SN1987A) during 2 hours 13 coincidences ware detected. Such large excess in the background level could be due to registration of neutrino interactions in the detectors.

Acknowledgements

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