10 Years Search for Neutrino Bursts with LVD

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1. Abstract

The Large Volume Detector LVD (Gran Sasso National Laboratory, Italy), is a neutrino telescope mainly designed to search for low energy neutrino bursts from Gravitational Stellar Collapses (GSC) in the Galaxy. The experiment has been monitoring the Milky Way since June 1992 under increasing larger configurations, reaching in January 2001 the final active mass of 1000 t. No burst candidate has been detected over all the ten years of observation: we present here the obtained limit to the rate of SuperNova (SN) event in the galaxy.

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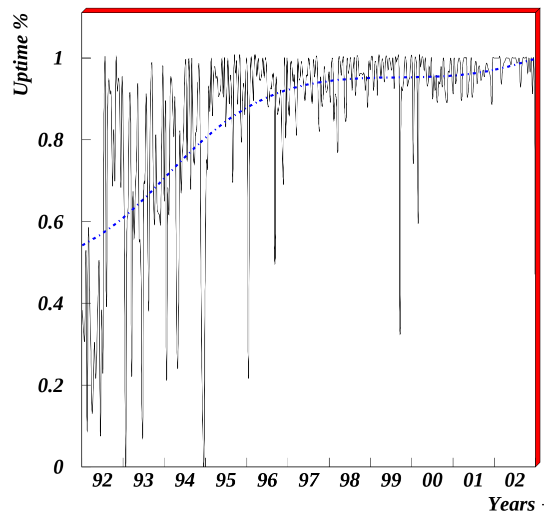

Fig. 1. Weekly averaged duty cycle in the LVD detector since June 1992.

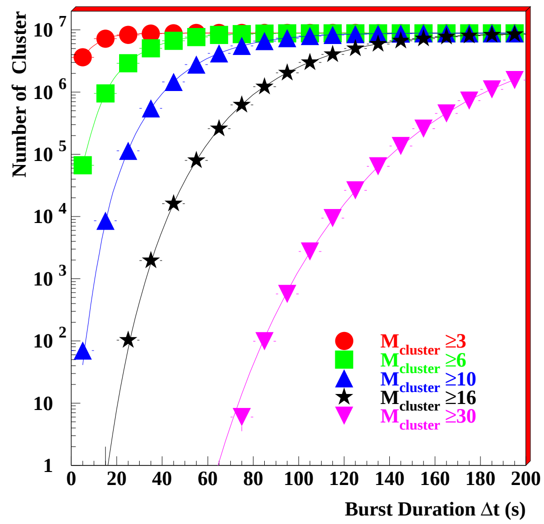

Fig. 2. Number of clusters of fixed multiplicity (m) and duration (Δt) detected in 2001-2003 compared to the expectations (solid lines).

2. Introduction

The LVD Detector consists of an array of 840 scintillator counters, 1.5 m^3 each, interleaved by streamer tubes, arranged in a compact and modular geometry (see [1] for a more detailed description), with an active scintillator mass $M = 1000$ t. The main purpose of the telescope is the detection of neutrinos from GSC in the Galaxy, mainly through the absorption interaction $\bar{\nu}_{\mathrm{e}}\mathrm{p}, \mathrm{e}^{+}\mathrm{n}$. This reaction is observed in LVD counters through two detectable signals: the prompt signal due to the e^{+} (detectable energy $E_{\mathrm{d}} \simeq E_{\bar{\nu}_{\mathrm{e}}} - 1.8$ MeV $+2\mathrm{m_e c}^2$), followed, with a mean delay $\Delta t \simeq 180$ μs, by the signal from the $\mathrm{np}, \mathrm{d}\gamma$ capture ($E_{\gamma} = 2.2$ MeV). Counters are divided in 2 subsets: the external ones (43%), operated at energy threshold $\mathcal{E}_h \simeq 7$ MeV, and inner ones (57%), better shielded from rock radioactivity and operated at $\mathcal{E}_h \simeq 4$ MeV. In order to tag the delayed γ pulse due to the n-capture reaction, all counters are equipped with an additional discrimination channel set at a lower threshold $\mathcal{E}_l \simeq 1$ MeV.

LVD has been taking data since June 1992 with a sensitivity high enough to cover the Galaxy. Figure 1. shows the duty cycle of the detector over more than 10 years of operation. Results on the neutrino bursts monitoring for the period 1992-2000 have been already reported [4] and no candidate for a supernova signal has been detected. In this note we present the off-line analysis of data collected since December 11^{th}, 2000 till March 24^{th}, 2003 and the on-line alarm selection algorithm.

3. The Off-line Analysis

The off-line search for ν burst candidate is performed by studying the temporal trigger sequence looking for signal clusterization. For each run, characterized by a fixed detector configuration (i.e. stable mass and counting rate) preliminary cuts are applied to reject signal contributions coming from non-optimal counters. The pulse energy of the ν events is required to belong to 7-100 MeV range and the muon signals are rejected. Informations contained in the general LVD Data Base, which is daily updated, are used. The neutrino burst candidate selection, widely discussed in [3], processes all possible clusters up to 200 s of duration, initiated by each single pulse belonging to the trigger sequence. For each selected cluster with multiplicity m and duration Δt, the Imitation Frequency IMF is calculated as a function of the cluster parameters and of the rate f_b of the background events. After this pure statistical selection a complete analysis of each detected cluster with IMF $\leq 1/year$ tests its consistency with a ν burst through: *a)* the study of topological distribution of pulses inside the detector; *b)* the energy spectrum of the events in the cluster; *c)* the characteristics of the time distribution of delayed low energy pulses. We present here the results obtained since December 11^{th} 2000 to March 24^{th} 2003 by using the off-line clustering technique. The analysis regards 7880592 events detected during 820 days, corresponding to an average frequency $f_b = 0.11\ Hz$. The multiplicity distributions of the clusters are shown in figure 2. compared to the expectations from the Poissonian fluctuations of the background: quite good agreement is observed. The sensitivity of the telescope at the level of 1 imitation event every 100 years is shown in fig. 3. where each detected cluster is represented by its multiplicity (m) and duration (Δt). Since the LVD sensitivity is higher than the expectations from GSC models, even if the source is at distance of 20 kpc and for soft neutrino energy spectra, we can conclude that no gravitational stellar collapse have been occurred in the Galaxy in the period of observation. Including the previous published results the upper limit to the rate of GSC in our Galaxy over 3511 days of live-time observation at 90% c.l. is: 0.2 $event/year$.

4. The On-line Alarm Selection

Since 1998 LVD participates to the SuperNova Early Warning System (SNEWS), an international collaboration connecting word-wide existing supernova neutrino detectors [5]. The main SNEWS goal is to provide a fast and very reliable alert to the astronomical community at the time of the next galactic supernova through the time coincidence of burst signals coming from different experiments. Each individual detector is expected to send its own alarms, selected by a burst detection algorithm that must be fast and highly efficient, with a background rate ($1/week$) that keeps the inter-experiments random coincidences rate

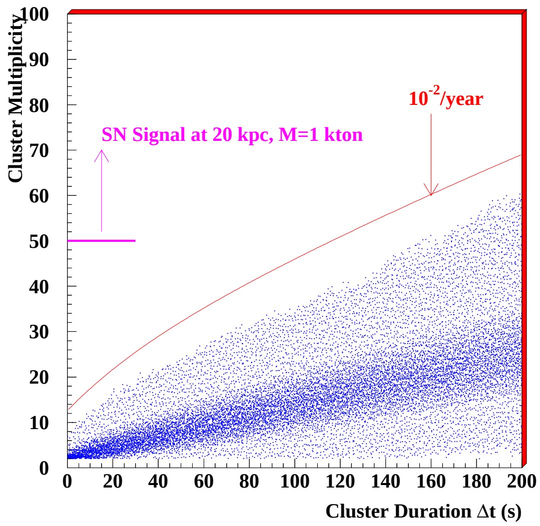

Fig. 3. Scatter plot $(m, \Delta t)$ of all detected clusters.

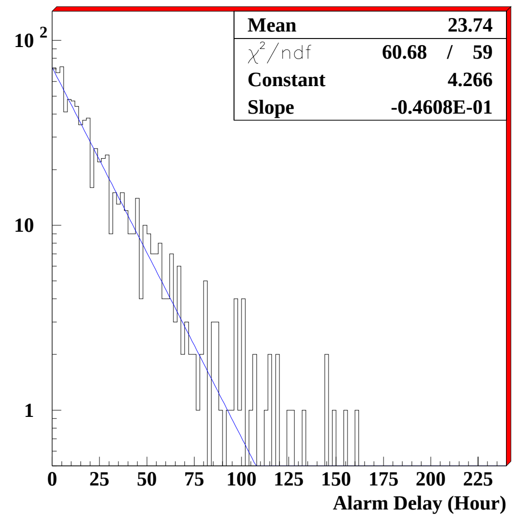

Fig. 4. Alarm delay distribution if 1/day rate is requested.

very low. Since 2001 an on-line selection technique, different from the off-line clustering mode, is used. Data are processed in fixed time windows of duration $\Delta t = 20\ s$, the Poissonian probability for each observed cluster multiplicity is calculated and, if lower than a fixed threshold, an automated alarm is sent to the SNEWS servers. In figure 4. the delay distribution between the alarms found in 820 days of live-time operation when the 1 alarm/day rate is required is shown: the observed mean delay corresponds to the selected one.

5. Conclusions

The Large Volume Detector has been monitoring the Galaxy over more than 10 years searching for neutrino signals from Gravitational Stellar Collapses. No burst candidate has been found over 3511 days of live-time observation and the upper limit 0.2 $event/year$ to the rate of GSC is obtained. Since 2001 an efficient on-line ν-burst monitor has been implemented to keep LVD connected to the SNEWS inter-experiment system.

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[5] SNEWS at http//:hep.bu.edu/∼snnet/ and references therein