Search for neutrino bursts from SN collapse with the Large Volume Detector

LVD Collaboration

Abstract

The Large Volume Detector of the Gran Sasso Laboratory has been running since June 1992 in the search for neutrino bursts from Supernova collapse with an average uptime efficiency $\bar{\epsilon} \simeq 80\%$ for the whole period.

The detector characteristics and methods used to search for burst candidates and to test their consistency with neutrino interactions are discussed.

We report on the results of the analysis of the period since 30^{th} April '97 till 15^{th} March '99. Since June 1992 no evidence for ν burst candidates has been found. On the basis of this data the upper limit at 90% c.l. on the rate of Gravitational Stellar Collapse in the Galaxy is $0.4\ events \cdot year^{-1}$.

1 Introduction:

The Large Volume Detector (LVD) is a neutrino telescope located in the Gran Sasso Underground Laboratory (Italy) at a minimum rock coverage of $3000\ m$ of water equivalent mainly devoted to study ν interactions from gravitational stellar collapses in our Galaxy. The LVD consists of liquid scintillator counters and streamer chambers. At present the active scintillator mass is $670\ t$.

On the ground of theoretical expectation on ν fluence from SN collapses LVD is well suited to detect the ν signal from events occurring everywhere in our Galaxy [LVD Coll. 1992]. Among all existing detectors of neutrinos from Gravitational Stellar Collapses LVD has two peculiarities: it is sensitive to low temperature ν emission because of the low energy threshold of the detector core and it is able to disentangle differend ν interactions.

2 The detector:

The main LVD characteristics are:

- detector modularity: the liquid scintillator is contained in stainless steel counters ($1.0 \times 1.0 \times 1.5\ m^3$ each) arranged in a compact geometry and surrounded by streamer chambers.
- energy threshold: $E_{th} \simeq\ 4\ MeV$ for the core counters (very well shielded to the radioactive background from the rock) and $E_{th} \simeq\ 7\ MeV$ for the external ones.
- average neutron detection efficiency $\simeq\ 60\%$ for each scintillation counter of the coreallowing the detection of both products (e^+ and n) of the interaction ($\bar{\nu}_e p, ne^+$) which dominates in hydrogen based targets.

The most important LVD performances connected to the search for ν bursts from gravitational stellar collapses are:

- The information related to each signal is stored in a temporary memory buffer which is shared by 8 scintillator counters. This buffer can store up to $2 \cdot 10^5$ pulses, which corresponds to the signal expected from a Supernova at a distance closer than $1\ kpc$ from the Earth.
- The total deadtime corresponds to a maximum detectable frequency of 500 kHz per counter. The read out procedure does not introduce any additional deadtime [Bigongiari et al. 1990].
- The time of each event, relative to the U.T. ($\pm 1\ \mu s$ from the G.P.S facility of the Gran Sasso laboratory), is measured with an accuracy of $\pm 12.5\ ns$.

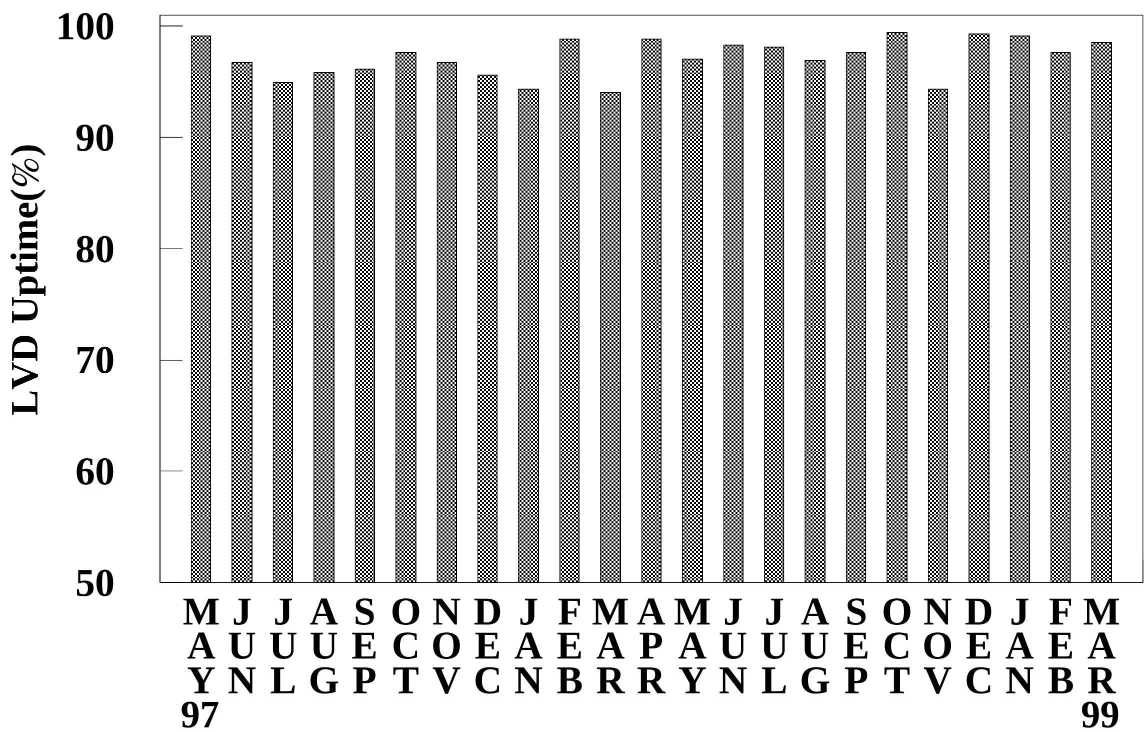

Figure 1: LVD monthly duty cicle during the period under study.

- The experimental duty cycle averaged since June '92, when the first LVD tower started taking data, is 80%. During the period May '97-march '99 the mean acquisition duty cicle was better than 97%. In figure 1 the mean monthly uptime is reported.

3 Results on Supernova neutrino analysis:

Since June 1992, LVD has been sensitive to neutrino bursts from stellar collapses in our galaxy [LVD Coll. 1992]. The on-line analysis (i.e. a high priority task which processes all the recorded pulses after muon rejection) is based on pure statistical analysis. The time sequence of clustered single pulses is checked and compared with the expected one. Each cluster is defined by the multiplicity m and the time duration Δt ($\Delta t \leq 200\ s$. The corresponding Poisson probability is calculated on the basis of the current trigger rate and an imitation frequency (F_{im}) is obtained [Fulgione et al. 1996].

If F_{im} of the candidate is less than $1\ event/day$, its consistency with a burst of neutrino interactions is tested. We expect that a ν burst should have pulses uniformely distributed over the whole detector while background pulses are distributed according to the measured counter exposure to the mountain rock. If the multiplicity of a single counter, inside a cluster of multiplicity m, is higher than a limit value the counter is excluded and all correlated pulses rejected. The survival cluster is checked again by the same technique.

If the candidate survives to this iterative procedure, having $F_{im} \leq 1\ event \cdot week^{-1}$, a notification mail is sent to a distribution list and all data informations (i.e. arrival time, energy and location inside the detector of each pulse) are written in the Candidates Data File.

The energy spectrum of the events in the cluster and the time distribution of existing delayed low energy pulses (which signals the occurrence of $\bar{\nu_e}$ interactions) would be analyzed in detail.

In a second time an off-line analysis is performed on each individual run using the same technique of the on-line procedure. The candidate selection and the background rejection criteria are implemented. Moreover

some informations concerning the quality of the data and the single counter response in each run, not available during the on-line procedure, are taken into account. These operations contribute to debug and calibrate the telescope counters.
The results of the off-line analysis since June '92 till April '97 have been published and discussed in [LVD Coll. 1993,1995,1997].

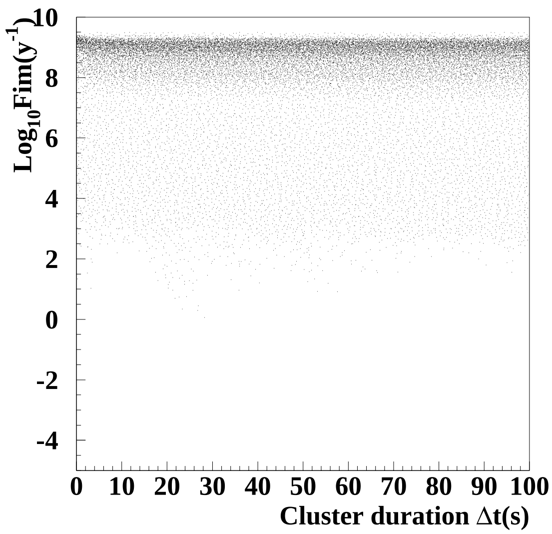

Figure 2: Backgorund cluster imitation frequency per year versus the cluster duration Δt.

In this paper we present the results of the off-line analysis of data collected by LVD since 30^{th} April 1997 till 15^{th} March 1999 for a total uptime of 685 days. Data of two LVD towers have been included: $18.385.034$ single pulses after muon rejection have been analysed and more than $1.5 \cdot 10^9$ clusters scanned. Figure 2 shows the bidimensional distribution of the imitation frequency $F_{im}(event \cdot year^{-1})$ of any recorded cluster, with $\Delta t \leq 100\ s$, versus the associated time duration. All selected clusters are compatible with the expectations from a Poisson distribution of the background. No eccess, with $F_{im} \leq 0.01/year$ has been observed. We can conclude than no burst candidate, even with a duration of some minutes (i.e. much longer than the expected duration of the ν emission from a stellar collapse) has been observed by LVD.

4 Conclusions:

The Large Volume Detector has been surveying our Galaxy since June 1992 to search for ν signals from Gravitational Stellar Collapses.

The detector characteristics allow us to study neutrino emission down to a few MeV due to SN explosions occurring everywhere in our Galaxy.

No event with the expected multiplicity and duration has been recorded during 2033 days of operation and we calculate an upper limit (90% c.l.) to the rate of Gravitational Stellar Collapse in our Galaxy of $0.4\ events \cdot year^{-1}$.

5 Acknowledgments:

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