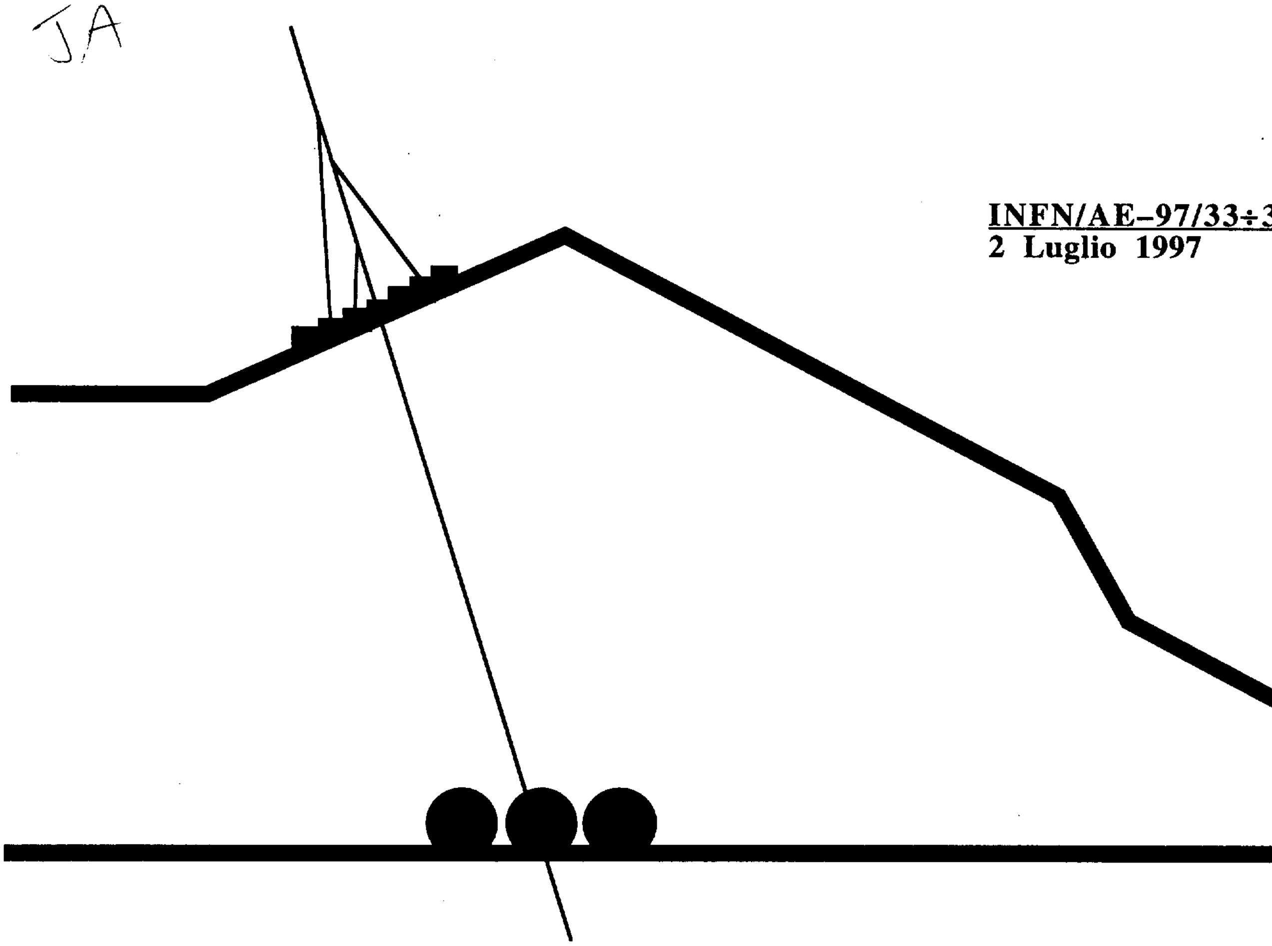

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LVD COLLABORATION

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STUDY OF NEUTRINOS FROM STELLAR COLLAPSES WITH THE LVD EXPERIMENT IN THE GRAN SASSO LABORATORY

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ABSTRACT

The Large Volume Detector (LVD) in the Gran Sasso Underground Laboratory is a ν observatory mainly designed to study low energy neutrinos from gravitational stellar collapses. The experiment is sensitive to collapses in our Galaxy since June 1992, nowaday with an active mass of about 560 tons.

The detector performances and the method used to search for Supernova events and to identify different neutrino interactions is presented. No evidence for burst candidates has been found untill april 1997, for a total lifetime of 1309 days.

INTRODUCTION

The Large Volume Detector is a neutrino telescope located in the Gran Sasso Underground Laboratory at a minimum depth of about 3000 m.w.e. The telescope consists of 2 kinds of detectors, namely: liquid scintillator, for a total mass of 1840 tons, and streamer tubes for a total surface of about 7000 m^2. At present $\approx 1/3$ of the detector is in operating conditions. The main purpose of the experiment is to study gravitational stellar collapses in our Galaxy by detecting its ν burst.

The main LVD characteristics connected to the search for ν burst are:

- detector modularity: 1840 tons of liquid scintillator contained into 1520 self-triggering counters;
- energy threshold: about 4 MeV for the core counters;
- average neutron detection efficiency: about 60%.

SUPERNOVA NEUTRINO DETECTION IN LVD

Most theoretical models agree in predicting the total energy emitted as ν 's during the stellar collapse, the energy equipartition among the different ν flavours and the time duration of the ν burst. Precisely, for a collapsing star at the distance of 10 Kpc, with ν-sphere temperatures $T_{\nu_e} = 3$ MeV and $T_{\nu_\mu} = 6$ MeV we have computed (Aglietta et al.,1992) a total of ≈ 400 interactions, in agreement within 5% with other calculations (A.Burrows et al.,1992).

For any scintillator detector the bulk of events (about 90% of the total number of interactions) is due to the capture reaction:

$$\bar{\nu}_e + p \to n + e^+ \qquad\qquad n + p \to d + \gamma_{2.2MeV}. \tag{1}$$

The possibility of detecting both products of reaction (1): e^+ and n, allows LVD to identify $\bar{\nu}_e$ interactions, and thus to measure the temperature of the $\bar{\nu}_e$ neutrino-sphere.

Further, we wish to recall that in LVD about 5% of the events are due to neutral current interactions with ^{12}C which deexcites emitting a 15.1 MeV γ. The detector efficiency on detecting these signals has been evaluated in (P.Antonioli et al.,1991). Because μ and τ neutrino-spheres are located deeper in the collapsing stellar core, and because of a temperature gradient, their energy spectra have higher temperatures as compared with the electron neutrino spectra. As a consequence more then 90% of the n.c. interactions with Carbon nuclei are produced by ν_μ and ν_τ.

Moreover, 3% of events in LVD, are due to elastic scattering of all neutrino flavours on electrons, and less then 1% to c.c. interactions of ν_e and $\bar{\nu}_e$ with ^{12}C nuclei. These reactions could easily be separated by subsequent β decay, but because of their relative high thresholds they are strongly suppressed. If energetic μ and τ neutrinos oscillate in electron neutrinos, the $\bar{\nu}_e$ spectrum will be distorced and c.c. interaction channel will open (O.G.Ryazhskaya et al.,1994).

DETECTOR PERFORMANCES

In the search for ν bursts from gravitational stellar collapses, the most important performances of LVD are the following.

- 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 10^5 pulses, which corresponds to the signal from a standard supernova at a distance closer then 1 Kpc from the Earth.
- The total deadtime corresponds to a maximum detectable frequency (per counter) of 500 kHz. The read out procedure does not introduce any additional deadtime.
- The time of each event, relative to the U.T. time ($\pm$ 1 μsec. from the Gran Sasso facility), is measured with an accuracy of $\pm$12.5 nsec.
- The experiment duty cycle averaged since June '92, when the first LVD tower started taking data, is 76%. Fig.1 shows the detail of the last year.

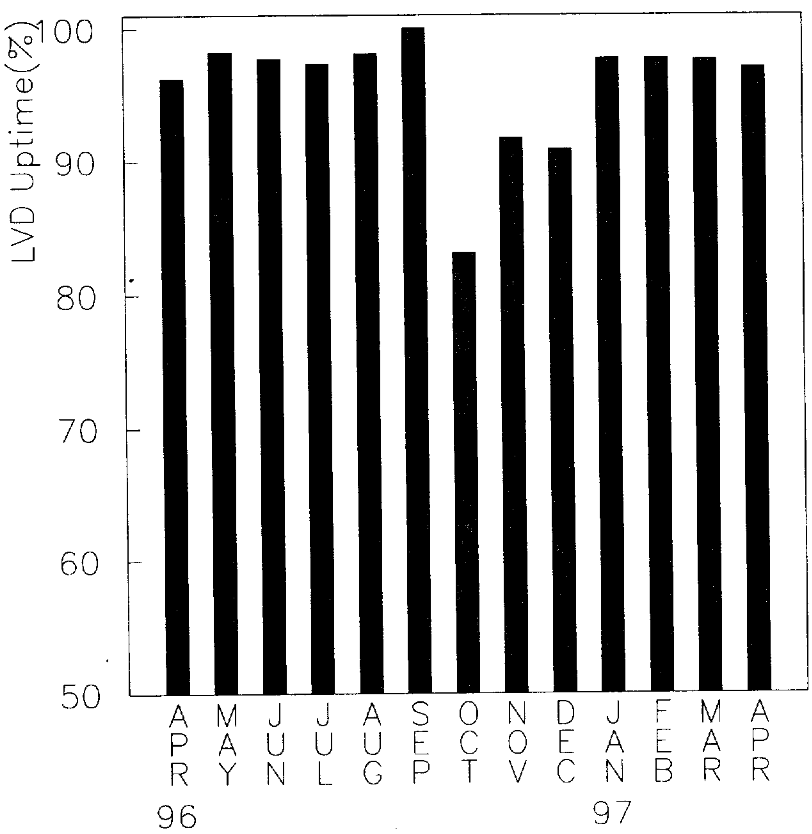

Fig. 1: LVD uptime during the last year of data taking

EVENT RECOGNITION AND NEUTRINO IDENTIFICATION

The search for ν burst candidates is performed by studying the trigger time sequences and searching for signal clusterization. The background due to cosmic ray muons is rejected by the tracking system. The total counting rate of the experiment after μ rejection is 0.2 Hz tower^{-1}, dominated by the internal counters which operate at a lower energy threshold ($E \geq 3-4$ MeV). At $E \geq 7$ MeV all LVD counters are active and the total counting rate is 0.06 Hz tower^{-1}, the ratio between the counting rate of external and internal counters is 3 (in LVD about 1/2 of the total mass belongs to the detector core).

Candidate selection and detector sensitivity:

The technique we use to select burst candidates and to evaluate their significance, explained in detail in (W.Fulgione et al.,1996), is operating (on-line on the experimental data stream) since June '92. We call this the Supernova On-line Monitor (SOM).

The detector sensitivity as a function of the burst duration for the LVD mass active at present (560 tons) is shown in Fig. 2. The two lines are obtained by setting the imitation frequency to 1 event/100 years, for the detector as a single telescope, and to 1 event/month for the detector inserted into a network. With the present LVD active mass, the survey of our full Galaxy is guaranteed, the Large and Small Magellanic Clouds will eventually become observable with LVD in the final configuration.

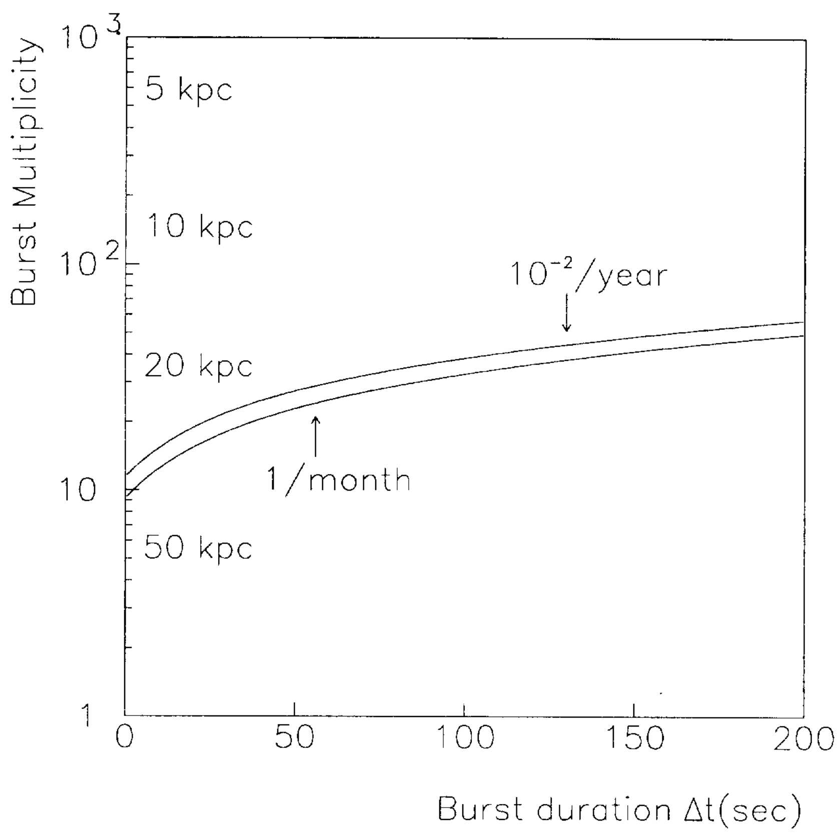

Fig. 2: Detector sensitivity for different durations of the ν emission (560 tons)

Neutrino identification:

After the selection of any cluster of pulses, by means of a pure statistical analysis based on their temporal sequence, the burst candidate is analysed to test its consistency with a ν signal. Three independent tests are performed:

a) presence of signals due to n-capture, from reaction (1);

b) event topology;
c) energy spectra.
a) The efficiency in detecting the 2.2 MeV photons from n-capture, measured on some counters by using a n-source (^{252}Cf), was found to be $\approx 60\%$. The average counting rate per counter for E ≥ 1 MeV is 120 sec^{-1}. On the average in a time window of 600 μsec the signal to noise ratio is about 10. Moreover the time distribution of these delayed signals is different in the case of background (flat distribution) or n-capture (exponential with mean life 185μsec).
b) Background events are concentrated in regions of the telescope more exposed to the natural radioactivity. Neutrino interactions must be uniformly distributed inside the volume of the detector. Thus we study the spatial distribution of events inside the telescope for each burst candidate by two independent methods.(W.Fulgione et al.,1996 and V.G.Ryasny,1996). Both methods, if we exclude the background contamination (that depends on the burst duration), are completely independent on the time features of the cluster, and they are very effective in rejecting burst candidates produced by non Poissonian fluctuation of the noise, namely electronic troubles.
c) The expected energy distribution of e^+ from $\bar{\nu}_e$ interactions strongly differs from the background energy spectrum (M.Aglietta et al.,1995). By studying the measured spectra one can also determine the temperature of the $\bar{\nu}_e$-sphere and the number of n.c. interactions on ^{12}C.

CONCLUSION
Since June '92, LVD is surveying our Galaxy in the search for ν burst from gravitational stellar collapses. During this period no candidate survived at the analysis at the level of 1 event every 100 year.

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