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Supernova neutrino detection with LVD

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We report on the Large Volume Detector (LVD), running as a Supernova neutrino telescope since June 1992. The LVD characteristics and performances are discussed in comparison with other detectors based on different techniques.

The ν signal expected in LVD from a gravitational stellar collapse in our Galaxy has been calculated in detail for different spectral characteristics of the ν emission.

1. Introduction

In the picture of all existing detectors of neutrinos from Gravitational Stellar Collapses (G.S.C.), the LVD scintillator detector has two peculiarities: it can operate at lower energy thresholds as compared to Cherenkov light detectors (because of a higher light yield and of a good light collection), and it can detect both products (e^+ and n) of the dominant interaction of $\bar{\nu}_e$ with free protons.

The detection of low energy neutrinos, of the order of a few MeV, gives the possibility to study objects emitting at low temperatures of the ν-sphere. Low temperatures, corresponding to neutrino average energies of a few MeV, are difficult to detect but surely cannot be excluded: neither by theoretical models, nor from the phenomenological point of view; indeed our experimental knowledge of the neutrino signal from G.S.C. is based on an single event with poor statistics and controversial energy spectrum [1].

Moreover, as pointed out in [2], a poor knowledge of the $\bar{\nu}_e$ spectrum in the low energy region (where the deviation from the standard Fermi-Dirac distribution could be strong) induces errors in determining the total $\bar{\nu}_e$ luminosity.

On the other hand the possibility to identify the $\bar{\nu}_e$ interactions with protons by a stringent signature (and not simply by the absence of directionality as for light water Cherenkov detectors) gives us the chance to play with pure $\bar{\nu}_e$ energy spectrum and to separate the rare, but very interesting, charged and neutral current interactions with C nuclei from the most common $\bar{\nu}_e$ interactions.

2. The Detector

The LVD detector located in the Gran Sasso Underground Laboratory at a minimum depth of 3000 m.w.e. has been operating as a Supernova neutrino observatory since June 1992. In its final configuration it will consist of about 1.8 kton of liquid scintillator contained in identical 1.5 m^3 steel counters, arranged in a compact geometry and surrounded by streamer chambers. Each counter operates in a completely independent way from any other counter. At present one third of the total mass is operational.

The main purpose of the LVD experiment is to study the neutrino fluence from Supernova explosions. The detector characteristics and performances, for what concern this item, are described in [3]. The detector sensitivity to G.S.C. in our Galaxy has been discussed both in the case of LVD as a single telescope, and for the detector inserted into a Supernova Network [4].

The LVD core-counters (about 60% of the total mass in its final configuration) are at present operating at an energy threshold lower than 5 MeV, and we plan to lower it even more. In order to avoid a decrease in the detector ability to select

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burst candidates due to a higher counting rate from the low energy background, the search for clusters of neutrino signals is made with different energy cuts by using the technique described in detail in [5]. The results of the search for neutrino signal from G.S.C. have been reported in [4]. In Fig.1 the result of the last year of data taking is shown.

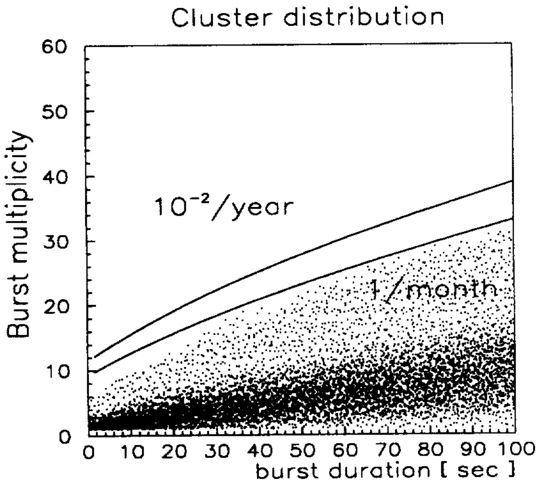

Figure 1. Scatter plot of the cluster of events detected in the last year of data taking, lines represent the detector sensitivity for different duration of the ν burst

3. ν interactions in LVD

The LVD experiment detects neutrinos of different flavours through different interaction channels. The most effective is the c.c. $\bar{\nu}_e$ interaction with free protons, but a significant amount of ν's can be detected through charged and neutral current interactions with ^{12}C nuclei. All these channels, besides the $\nu_i + e^-$ scattering, are characterized by stringent signatures and hence can be separated.

In order to estimate the number of expected interactions in the different ν channels we assume energy equipartition among flavours and Fermi-Dirac spectra with eventually non zero chemical potential, in agreeement with most models.

The temperature of the ν-sphere is given by: $T_{\nu_e} = T_{\bar{\nu}_e}$ and $T_{\nu_\mu} = T_{\bar{\nu}_\mu} = T_{\nu_\tau} = T_{\bar{\nu}_\tau} = \alpha\ T_{\bar{\nu}_e}$ for the different flavours, where α affects the number of n.c. interactions with C nuclei but only marginally acts on the total number of interactions. In the present calculation we used α=2.

In Fig.2 the total number of interactions expected in LVD for a G.S.C. at 10 Kpc emitting $E_{\nu_{tot}} = 3\ 10^{53}$ erg is shown versus the average $\bar{\nu}_e$ energy.

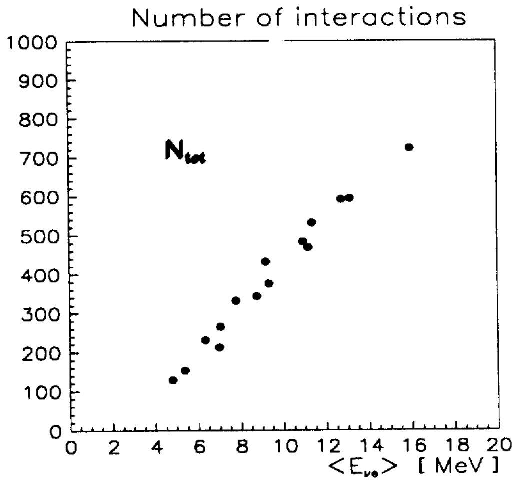

Figure 2. Total number of expected interactions vs. the $\bar{\nu}_e$ average energy

We tested different parameters of the $\bar{\nu}_e$ spectrum with $T_{\bar{\nu}_e}$ ranging between 1.5 and 3.5 MeV and $\eta = \mu/T$ ranging between 0 and 4; this corresponds to an average $\bar{\nu}_e$ energy between 4.7 and 15.6 MeV.

In order to avoid the dependence on the distance (D) and the luminosity (L_{ν_i}) of the source, the ratio between the number of interactions in the n.c. and c.c. channels with C to the total number of interactions has been plotted in Fig.3

for the same range of spectral parameters, carefully taking into account detector efficiency [6].

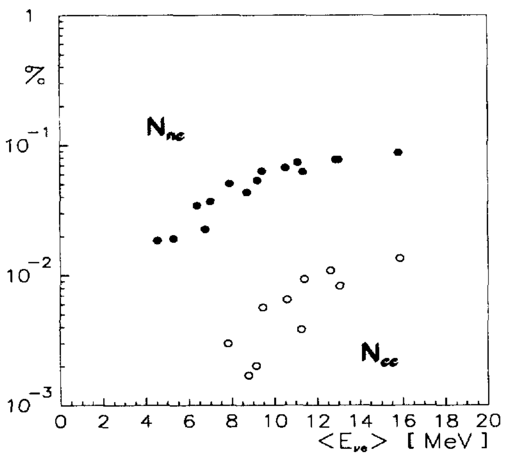

Figure 3. Percentage of interaction in n.c. and c.c. channels with ^{12}C with respect to the total number of interactions vs. the $\bar{\nu}_e$ average energy.

4. Conclusions

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

The detector characteristics allow us to study neutrino emission down to few MeV, in such a way investigating also galactic objects emitting ν's at low temperatures.

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