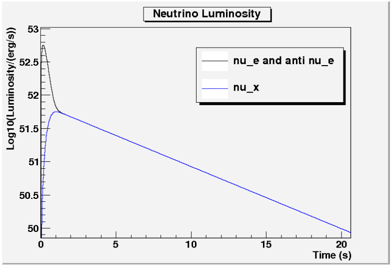
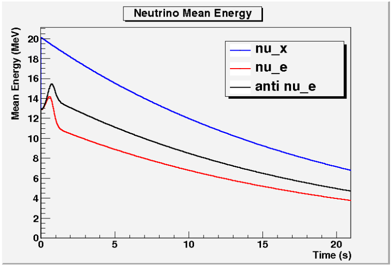
The Large Volume Detector (LVD)

A. Molinario

May 7, 2015

A core-collapse supernova (CCSN) emits all species of ν and $\bar{\nu}$ in a time scale of the order 10 s.





Pagliaroli et al., Astroparticle Physics 31, 163 (2009)

Requested features for a CCSN ν detector

Low neutrino cross section with nuclei

High mass (O(kt))

CCSN rare event in the Galaxy (1/30-50 y)

Long lasting (O(30 y))

Neutrino emission is short ($\sim$ 10 s)

Always active

Neutrino emission could be the only detected signal from CCSN in our Galaxy

Stand-alone detection capability

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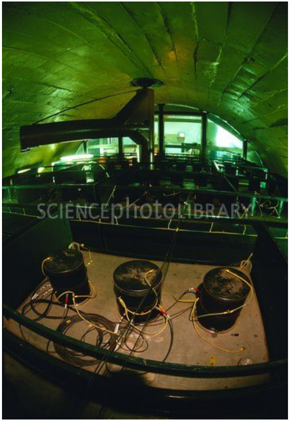
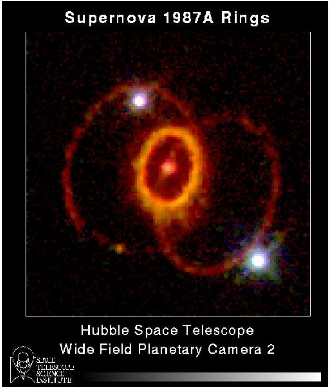
A bit of history...

The concept of a powerful ν detector was one of the motivation of the LNGS project itself. LVD project was approved in 1985 (even before SN1987A), with the same principle as the former LSD detector at Mont Blanc (1984-1999).



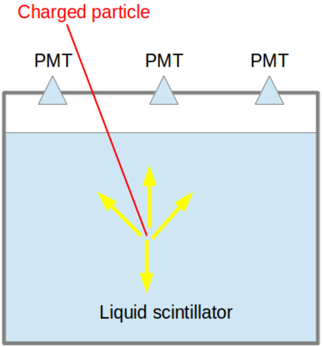


LVD is a 1 kt liquid scintillator detector in Hall A at LNGS. It started data taking in 1992.

Liquid scintillator

The liquid scintillator is both the target and the active material.

$$C_n H_{2n+2} \ , < n > = \ 9.6 \qquad (1)$$



The passage of a charged particle causes scintillation. The light is detected by Photomultipliers (PMTs).

The detector in a nutshell

A scintillator counter

Steel tank containing 1.2 t of liquid scintillator. 3 PMTs on the top.

A module

8 counters are grouped together to form a *module*.

3 towers

35 *modules* constitute a *tower*. LVD is made of 3 *towers* in total.

Compact and modular geometry. Each *tower* is independent from the point of view of power supply and data acquisition.

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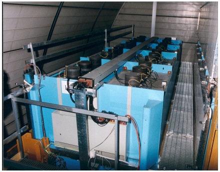

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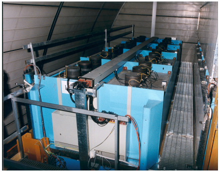

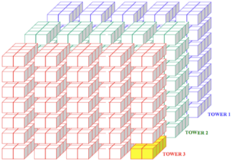

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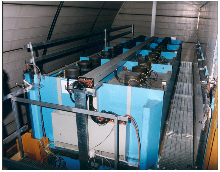

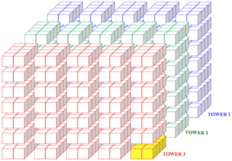

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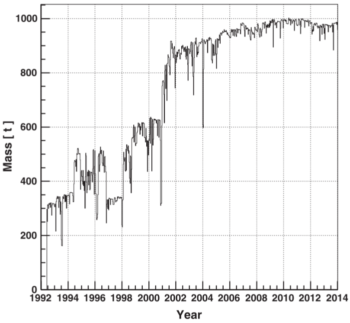

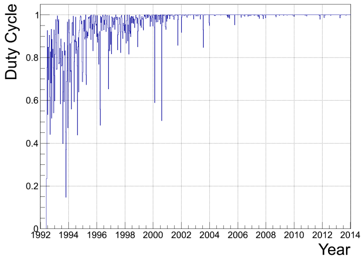

LVD reached its final configuration in 2001.

LVD can be serviced even during data taking. This implies a very high duty cycle.

ν detection

The main interaction with which ν from CCSN can be detected in LVD is IBD

$$\bar{\nu}_e + p \rightarrow n + e^+ \quad (2)$$

It is followed by neutron capture

$$n + p \rightarrow d + \gamma_{2.2MeV} \quad (3)$$

Other interactions, both CC and NC with electrons, Carbon and Iron nuclei, are detectable.

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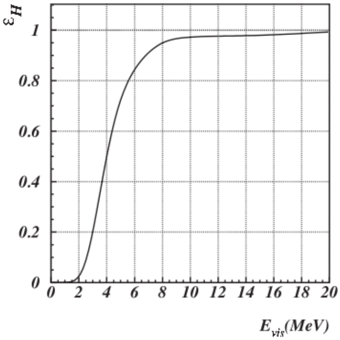
Trigger and Data Acquisition

The trigger is optimized for the detection of both products of IBD.

Trigger condition

3-fold coincidence of the 3 PMTs of any counter.

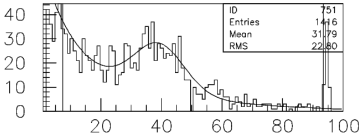
Two levels of discrimination:
$\epsilon_H \sim 4$ MeV is the main trigger condition.
$\epsilon_L \sim 0.5$ MeV is active only for 1 ms after a trigger, to look for n,p captures.



The summed PMTs signals are digitized and acquired.

Calibration and μ tagging

A μ passing through a counter releases in average $E_\mu = 185\,\text{MeV}$. A μ is identified as a tight temporal coincidence among at least 2 counters. Monthly energy calibration of all counters looking at the μ peak.



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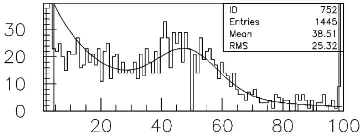

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LVD as a supernova ν observatory

Pure statistical selection of ν burst candidates.

Online

Automatic cluster selection with a fixed time window $\delta t = 20\,\mathrm{s}$.
Partecipation to SNEWS.

Offline

Analysis on all data set 1992/6/9 to 2013/12/31, **7335** days live time.

Data selection

At the trigger level, the bulk of events in the LVD are due to natural radioactivity products, both from the rock surrounding the detector and from the material that constitutes the detector itself, and to atmospheric muons.

- Exclusion of bad working counters
- Exclusion of μ events
- Selection of energy $10 \leq E_{signal} \leq 100$ MeV

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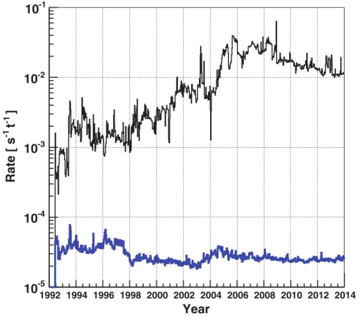
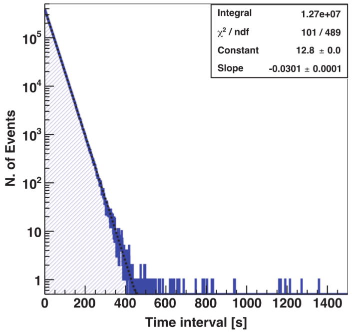


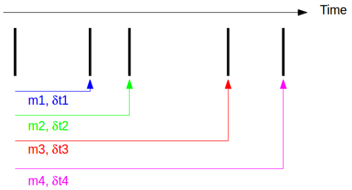
The thin black curve is the trigger rate before any cut, the thick blue one is the rate after the quality cuts have been applied.



Distribution of normalized time intervals between consecutive events. The dashed black line is a Poissonian fit.

Search for ν burst candidates

A cluster is a sequence of signals (triggers) with a multiplicity *m* inside a time window δt.



With which frequency F_{im} is the background able to produce, by chance, a cluster with $(m, \delta t)$?

$$F_{im} = f_{bg}^2 T_{max} \sum_{k \geq m-2} P(k, f_{bg} \cdot \delta t) \quad (4)$$

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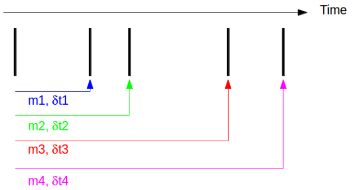

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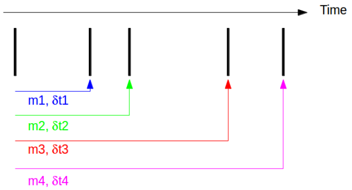

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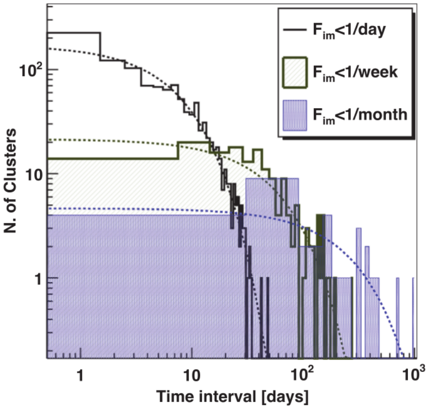
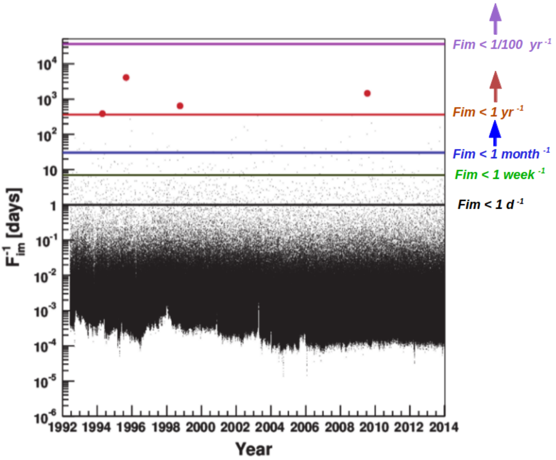


The good agreement between the data and the expected Poissonian behavior shows that the search algorithm and the detector are under control over the whole period of data taking.

Search for ν burst candidates

A total of 26,914,419 clusters with m≥2 and $T_{max} = 100\,\mathrm{s}$



You have to take data for 21 years to draw this picture!

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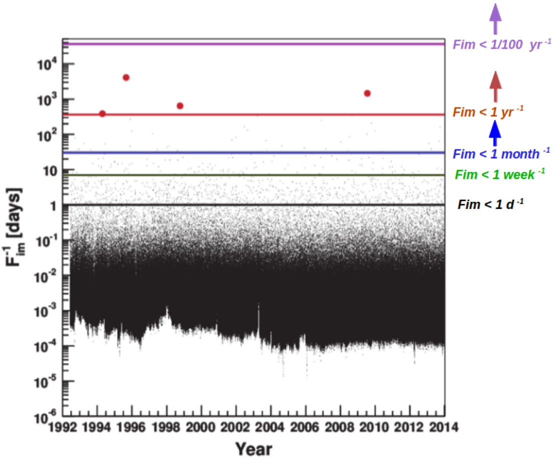

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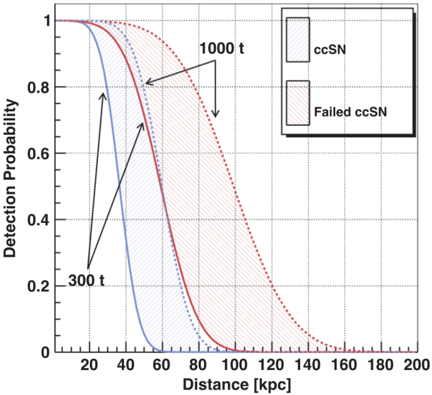

LVD detects standard CCSN and failed supernovae occurring in all our Galaxy when its active mass is greater than 300 t.

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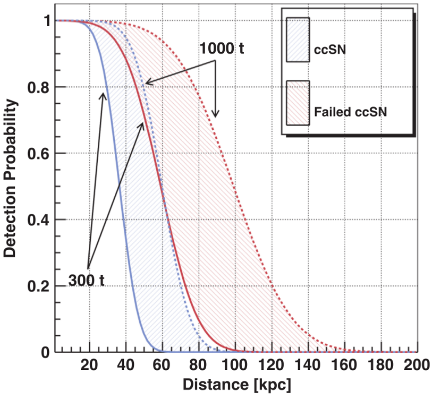

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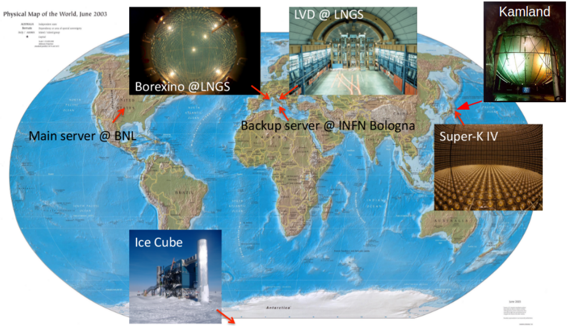
Results

No evidence is found for core-collapse or failed supernovae during the considered data-taking period. Taking into account the live time of 7335 days, we obtain a limit on the rate of gravitational collapses out to 25 kpc of less than 0.114 per year at 90% C.L.

Agafonova et al., The Astrophysical Journal 802:47 (2015)

SNEWS

The Supernova Early Warning System (SNEWS) looks for coincidences among ν detectors around the world, to provide a very high confidence early warning of the supernova's occurrence.



Get your own supernova alert: snews.bnl.gov/alert.html


PROJETMAN
PORTATA t40