LVD status report: neutrino physics.

LVD COLLABORATION

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Large Volume Detector (LVD)
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Large Volume Detector (LVD)
Large Volume Detector (LVD)

- The largest iron-scintillation telescope in the world
- 3 towers, 7 levels, 5 columns:
  - 840 scintillation counters situated in 105 portatanks (1010 tons of scintillator, 1000 tons of iron)
- Each portatank contains 8 counters
- Counter size is 1 m x 1 m x 1.5 m:
  - Total mass: 1020 kg of CnH2n scintillator
- 3 PMT of Russian production
Neutrino signal detection
SuperNova Early Warning System (SNEWS)

\[ \overline{E}_{\nu_e} = 12\,\text{MeV} \]
\[ \overline{E}_{\nu_e} = 10\,\text{MeV} \]
\[ \overline{E}_{\nu_\mu, \nu_\mu} = (20 - 25)\,\text{MeV} \]
\[ \overline{E}_{\nu_e, \nu_\mu} = (20 - 25)\,\text{MeV} \]
Neutrino signal detection

Registration of supernovae explosion with N pulses in the short period of time $T$

Average counting rate in the LVD detector is about 0.04 events per second

Time distributions of events in the LVD detector.
Neutrino signal detection

<table>
<thead>
<tr>
<th>n.</th>
<th>UTC</th>
<th>$M_{\text{act}}[t]$</th>
<th>$f_{blk}[s^{-1}]$</th>
<th>$D_{90%}[kpc]$</th>
<th>m</th>
<th>$\Delta t[s]$</th>
<th>$F_{im}^{-1}[/\text{years}]$</th>
<th>$E_{\text{signal}}[\text{MeV}]$</th>
<th>$N_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1994 16 April 10:40:49.263</td>
<td>346</td>
<td>$1.08 \cdot 10^{-2}$</td>
<td>29.5</td>
<td>7</td>
<td>18.88</td>
<td>1.06</td>
<td>26.5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1995 27 August 16:18:10.478</td>
<td>431</td>
<td>$1.85 \cdot 10^{-2}$</td>
<td>35.0</td>
<td>7</td>
<td>5.49</td>
<td>11.16</td>
<td>36.2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1998 7 October 15:41:41.775</td>
<td>552</td>
<td>$1.40 \cdot 10^{-2}$</td>
<td>30.6</td>
<td>12</td>
<td>90.05</td>
<td>1.76</td>
<td>32.2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>2009 18 July 7:39:20.517</td>
<td>976</td>
<td>$2.40 \cdot 10^{-2}$</td>
<td>40.4</td>
<td>12</td>
<td>42.71</td>
<td>4.02</td>
<td>14.6</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2014 25 May 3:54:14.555</td>
<td>959</td>
<td>$2.78 \cdot 10^{-2}$</td>
<td>36.8</td>
<td>14</td>
<td>61.56</td>
<td>1.49</td>
<td>22.6</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>2014 18 December 20:21:28.787</td>
<td>937</td>
<td>$2.33 \cdot 10^{-2}$</td>
<td>45.9</td>
<td>8</td>
<td>9.98</td>
<td>3.22</td>
<td>18.8</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 1:** Characteristics of clusters with significance $F_{im} < 1 \cdot \text{year}^{-1}$. 
Signature of signal in LVD in the case of $\tilde{\nu}_e$ detecting

\[
\tilde{\nu}_e + p \rightarrow e^+ + n
\]

The energy threshold for first signal from event in counter is 5 MeV

\[
\begin{align*}
n + H &\rightarrow d + \gamma \quad (E_{\gamma} = 2.2 \text{ MeV}) \\
n + ^{56}\text{Fe} &\rightarrow ^{57}\text{Fe} + \sum \gamma \quad (E_{\gamma} = 10.16 \text{ MeV})
\end{align*}
\]

$\tau \approx 185 \mu s$

Signature of signal in LVD in the case of $\nu_e$ detecting

\[
\nu_e + \frac{56}{26}\text{Fe} \rightarrow \frac{56}{27}\text{Co}^* + e^-,
\]

$\frac{56}{27}\text{Co}^* \rightarrow \frac{56}{27}\text{Co} + \sum \gamma, \quad E_{\gamma} = 7 \div 11 \text{ MeV}$

and

\[
\nu_i + ^{12}\text{C} \rightarrow ^{12}\text{C}^* + \nu_i, \quad (i = e, \mu, \tau);
\]

$^{12}\text{C}^* \rightarrow ^{12}\text{C} + \gamma, \quad E_{\gamma} = 15.1 \text{ MeV}$
In the case of Standard collapse model

<table>
<thead>
<tr>
<th>Detector</th>
<th>Depth m.w.e</th>
<th>Mass, ktons</th>
<th>Threshold, MeV</th>
<th>Efficiency</th>
<th>Number of events</th>
<th>Background s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVD</td>
<td>3300</td>
<td>1.0 CₙH₂ₙ</td>
<td>4 – 6</td>
<td>0.9</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.95 Fe</td>
<td></td>
<td>0.6</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>250*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>110*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>

Detector is ready to search for neutrino radiation from the collapsing stars, but the nature is miserly for the presents.

LVD is possible to detect not only electron antineutrino via the inverse beta decay reaction but also electron neutrinos due to their interaction with iron and other types of neutrinos via interaction on carbon nuclei.

Limit on the rate of gravitational stellar collapses in our Galaxy: 

**0.082 events · year⁻¹ at 90% c.l.**
LVD and BUST correlation
BUST

- Locates at North Caucasus
- Effective depth 850 mwe.
- $17 \times 17 \times 11 \, m^3$ in size and consists of four horizontal and four vertical plates
- 3184 scintillation counters

- Counter size is $0.7 \, m \times 0.7 \, m \times 0.3 \, m$:
  - Total mass: 300 tons of CnH2n scintillator
During SN1987A

Timing diagram of registered events from SN 1987A.

February 23, 1987. Large Magellanic Cloud. Distance ~ 50 kpc

Timing diagram of the BUST pulses coincident with the LSD pulses within 1 s and similar coincidences for the K2 and LSD detectors as well as double pulses in LSD over the period from 0:00 to 10:00 UT on February 23, 1987.

LSD-BUST: within 2 hours 13 coincidences
LVD and BUST correlation, 2011-2014 yy.

5 coincidences per day recorded only twice during 4 years of readout experimental data.
GW 170817

10 days before and after GW 170817
Neutrino velocity
Special beam structure from 10.05.2012 up to 24.05.2012
- 4 batch mode
- Time between modes is 300 ns
- Time inside one mode between signals is 100 ns
- $1.89 \cdot 10^{17}$ protons on target (p.o.t.)

$\langle E_\nu \rangle = 17$ GeV

$L_{\text{CERN-LVD}} \approx 731$ km
Neutrino velocity

\[ \delta t = -0.3 \pm 0.6 \text{ (stat.)} \pm 3.2 \text{ (syst.) ns} \]

\[-3.3 \times 10^{-6} < (v - c)/c < 3.5 \times 10^{-6} \]

\[ m_{\nu} < 44 \text{ MeV/c}^2 \text{ (99\% confidence level)} \]

48 events total
Summary

The report will present the results for 28 years of the experiment's existence.

New limit has been set on the frequency of supernova detection in our Galaxy: 0.082 events \cdot year^{-1} at 90% c.l.

The results of the correlation analysis between detectors LVD and BUST are presented: 5 coincidences per day recorded only twice during the 4 years of readout experimental data, results for GW170817 seems like background events

Neutrino velocity limit measured by LVD is:

\[-3.3 \times 10^{-6} < (v - c)/c < 3.5 \times 10^{-6}\]

\[m_\nu < 44 \text{ MeV/c}^2 \text{ (99% confidence level)}\]
Thank you!