ICPPA 2020

LVD status report: neutrino physics.

LVD COLLABORATION

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Large Volume Detector (LVD)

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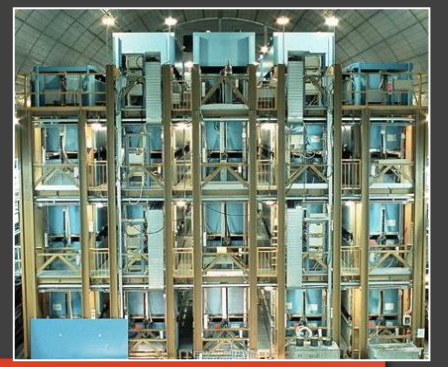
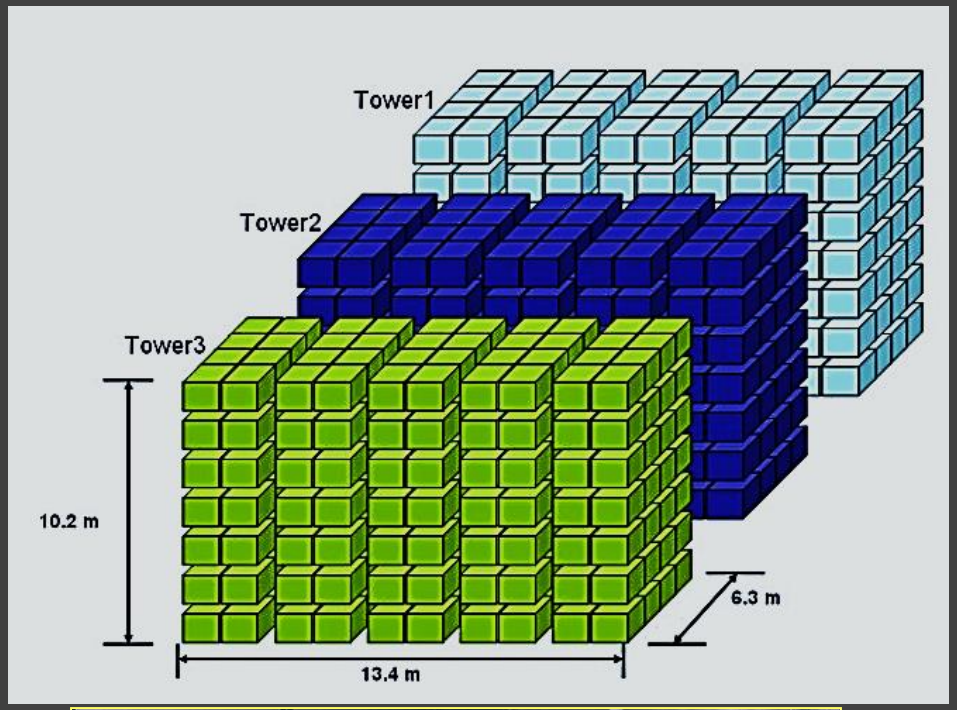
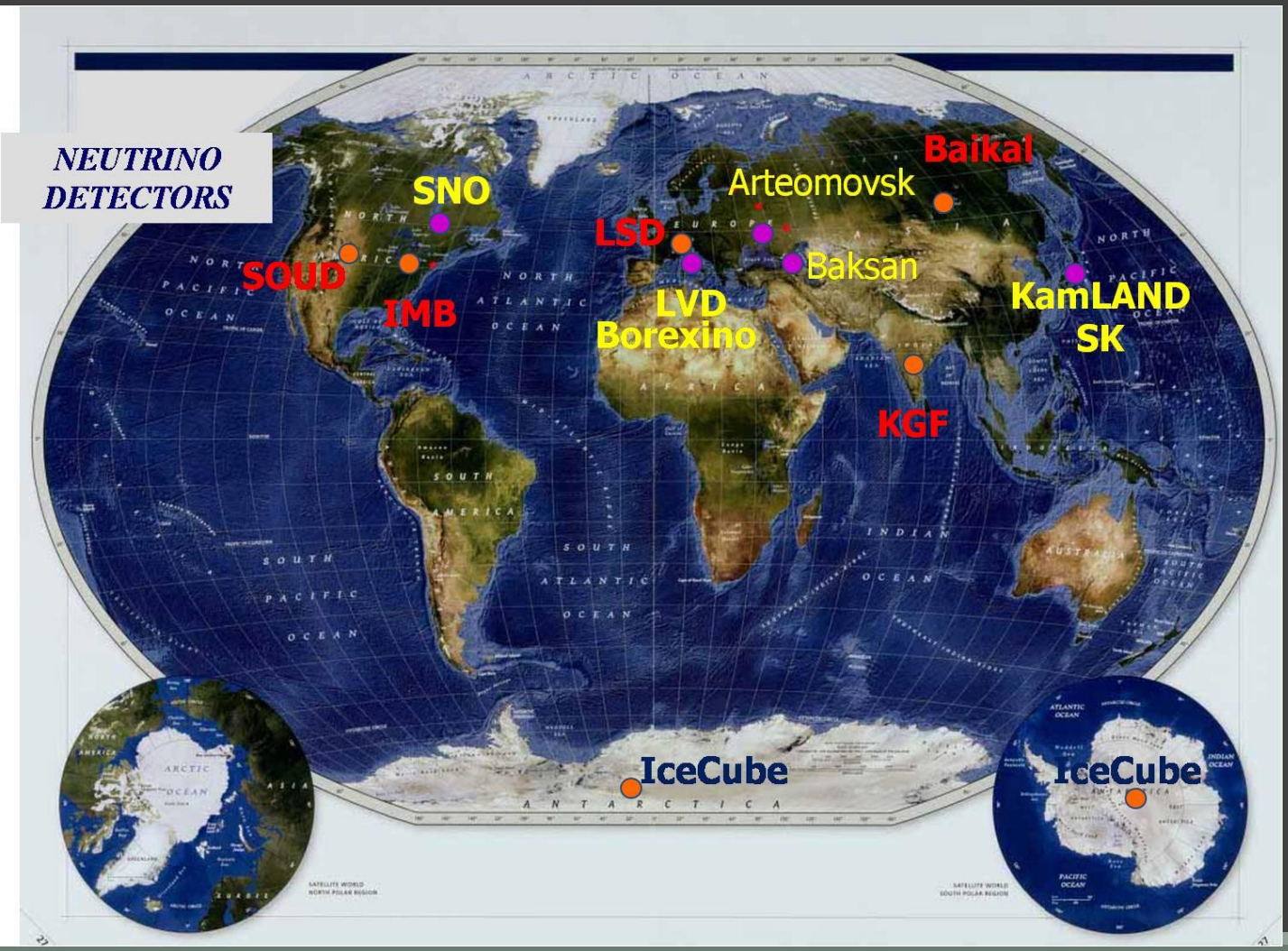




- ✓The largest iron-scintillation telescope in the world
- ✓3 towers, 7 levels, 5 columns:
  - ✓840 scintillation counters situated in 105 portatanks (1010 tons of scintillator, 1000 tons of iron)
- ✓Each portatank contains 8 counters
- ✓Counter size is 1 m x 1 m x 1,5 m:
  - ✓Total mass: 1020 kg of C_nH_{2n} scintillator
  - ✓3 PMT of Russian production

Neutrino signal detection

SuperNova Early Warning System (SNEWS)



$$\overline{E}_{\tilde{\nu}_e} = 12 MeV$$

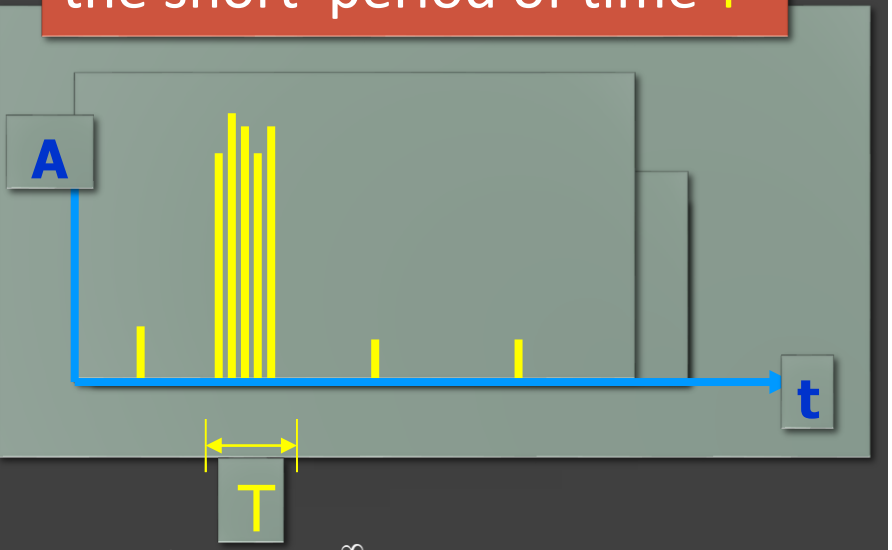
$$\overline{E}_{\nu_e} = 10 MeV$$

$$\overline{E}_{\nu_\mu, \tilde{\nu}_\mu} = (20 - 25) MeV$$

$$\overline{E}_{\nu_\tau, \tilde{\nu}_\tau} = (20 - 25) MeV$$

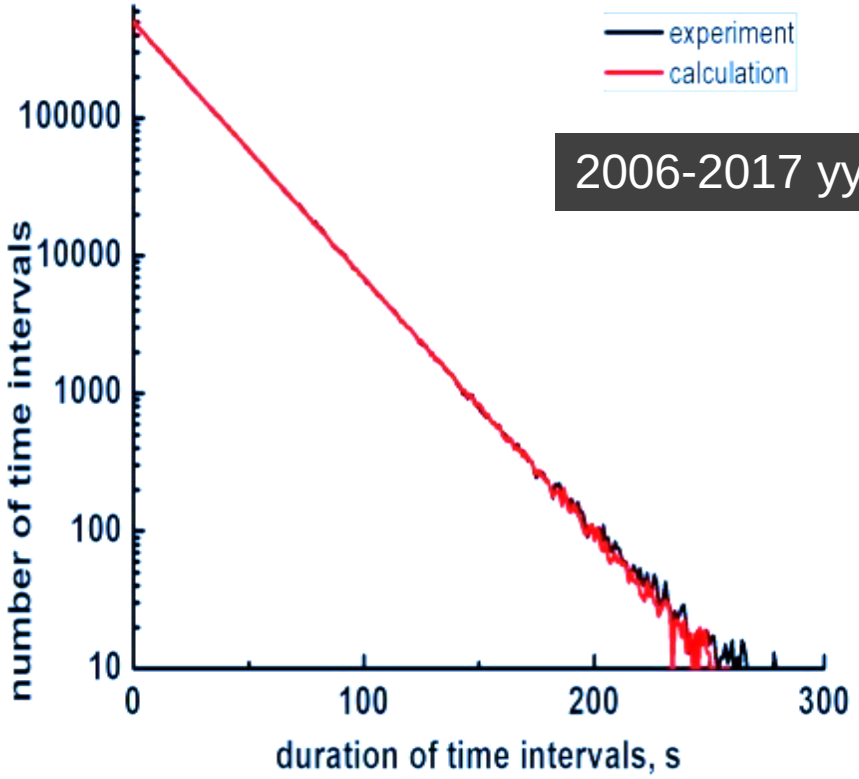
Neutrino signal detection

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



$$N \sim \frac{1}{4\pi R^2} \cdot \sum_i \int_{E_{thr}}^{\infty} I_{\nu_i}(E_{\nu_i}) \cdot \sigma(E_{\nu_i}) dE \cdot M$$

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

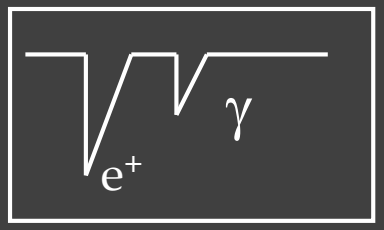
n.	UTC	$M_{act}[t]$	$f_{bk}[s^{-1}]$	$D_{90\%}[kpc]$	m	$\Delta t[s]$	$F_{im}^{-1}[years]$	$\bar{E}_{signal}[MeV]$	N_L
1	1994 16 April 10:40:49.263	346	$1.08 \cdot 10^{-2}$	29.5	7	18.88	1.06	26.5	2
2	1995 27 August 16:18:10.478	431	$1.85 \cdot 10^{-2}$	35.0	7	5.49	11.16	36.2	1
3	1998 7 October 15:41:41.775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

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



$$\left.\begin{array}{c} n + H \rightarrow d + \gamma \ (E_\gamma = 2.2 MeV) \\ n + {}^{56}Fe \rightarrow {}^{57}Fe + \sum\gamma \ (E_\gamma = 10.16 MeV) \end{array}\right\} \tau \approx 185 \mu s$$

Signature of signal in LVD in the case of ν_e detecting

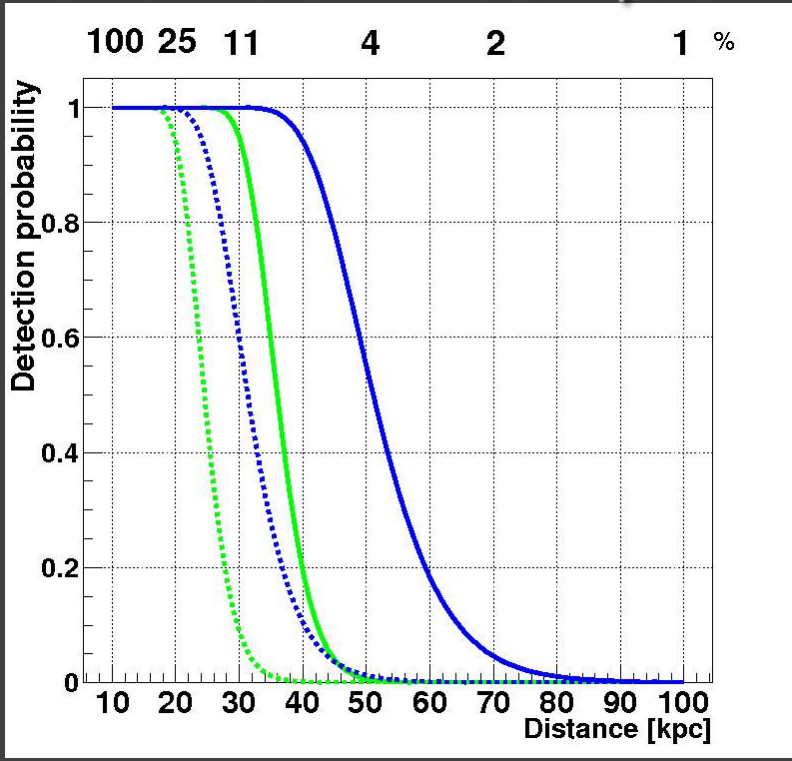
$$\nu_e + {}^{56}_{26}Fe \rightarrow {}^{56}_{27}Co^* + e^-, \quad {}^{56}Co^* \rightarrow {}^{56}Co + \Sigma\gamma, \ E_\gamma = 7 \div 11 MeV$$

and $\nu_i + {}^{12}C \rightarrow {}^{12}C^* + \nu_i, \ (i = e, \mu, \tau); \quad {}^{12}C^* \rightarrow {}^{12}C + \gamma, \ E_\gamma = 15.1 \ MeV$

Detector	Depth m.w.e	Mass, ktons	Thre-shold, MeV	Efficiency			Number of events					Back-ground s^{-1}
							Standard model			Collapsar Rotation model		
				η_{e+}	η_n	η_γ	$\bar{\nu}_e p$	$\nu_i e^-$	$\nu_i C$	$\nu_e A$	$\nu_e C$	
LVD Italy, Russia	3300	1.0 C_nH_{2n} 0.95 Fe	4 – 6	0.9	0.6	0.55 0.45	500	22	55	250* 100**	110* 50**	< 0.1

* - E=40 MeV
** - E=30 MeV

In the case of Standard collapse model



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:

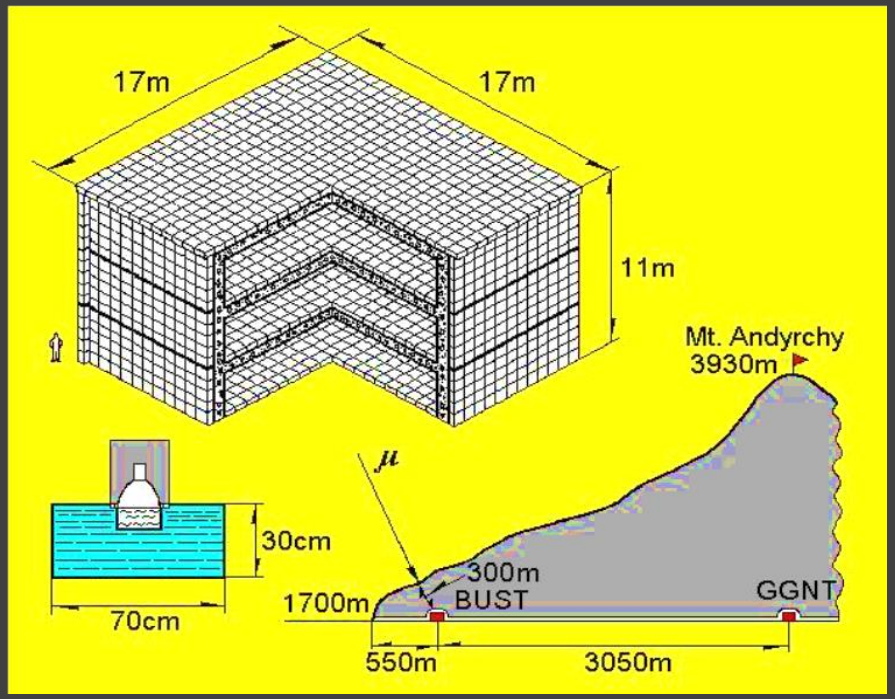
0.082 *events* · *year* $^{-1}$ at 90% c.l.

LVD and BUST correlation

BUST

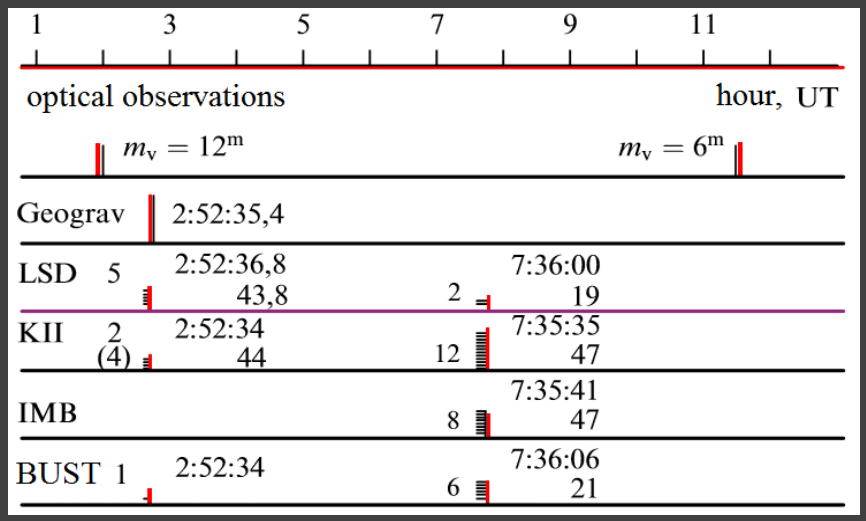
- ✓locates at North Caucasus
- ✓effective depth 850 mwe.
- ✓17 × 17 × 11 m^3 in size and consists of four horizontal and four vertical plates
- ✓3184 scintillation counters

- ✓Counter size is 0.7 m x 0.7 m x 0.3 m:
  - ✓Total mass: 300 tons of C_nH_{2n} scintillator

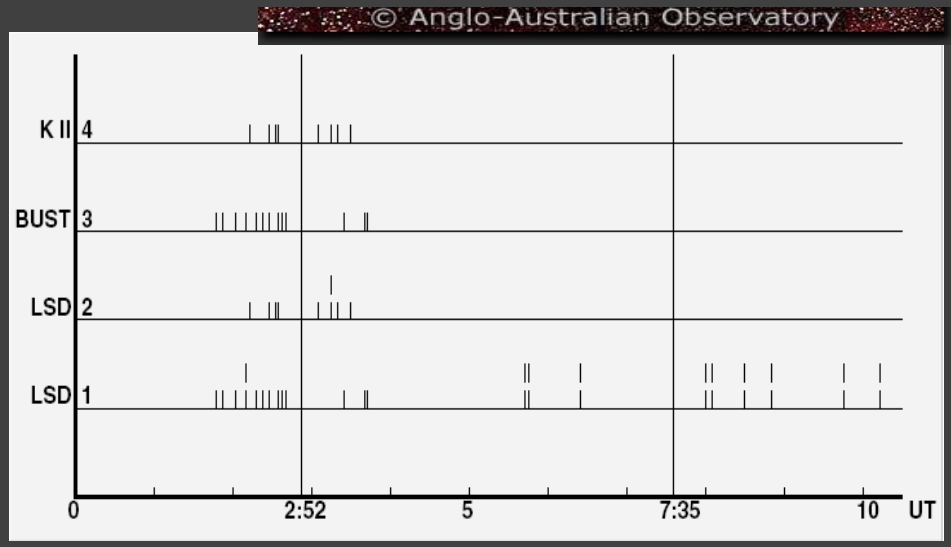


During SN1987A

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



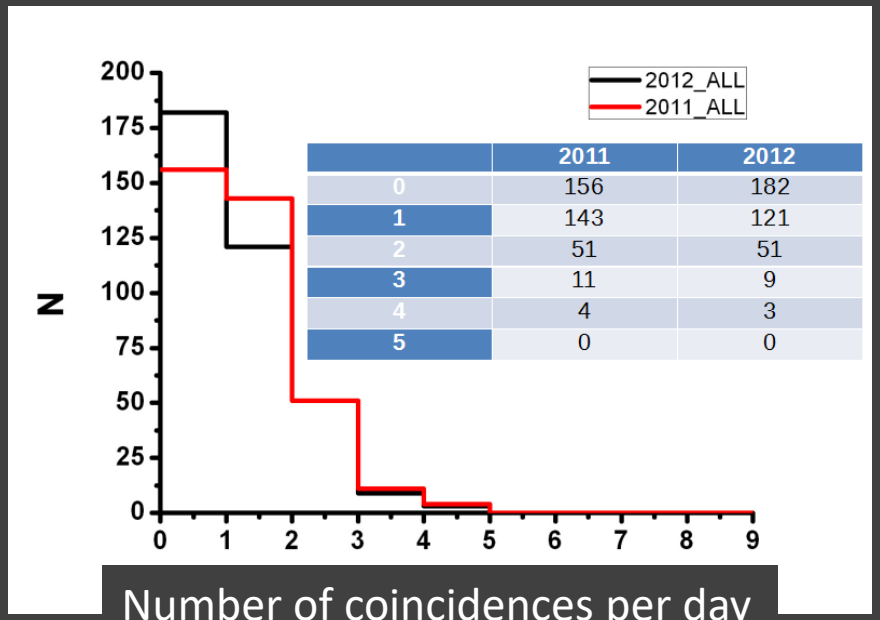
Timing diagram of registered events from SN 1987A.



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.

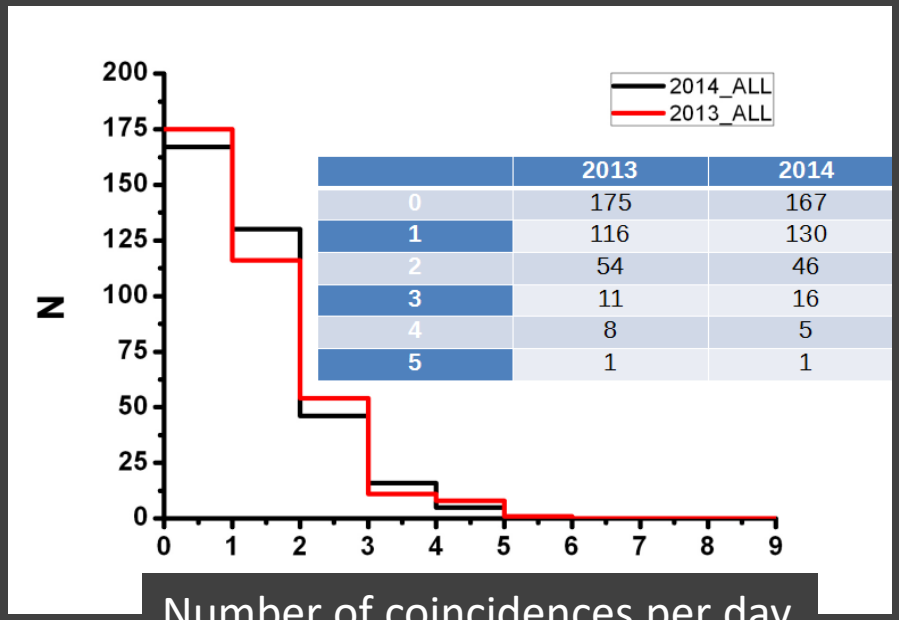
LSD-BUST: within 2 hours 13 coincidences

LVD and BUST correlation, 2011-2014 yy.



	2011	2012
0	156	182
1	143	121
2	51	51
3	11	9
4	4	3
5	0	0

Number of coincidences per day

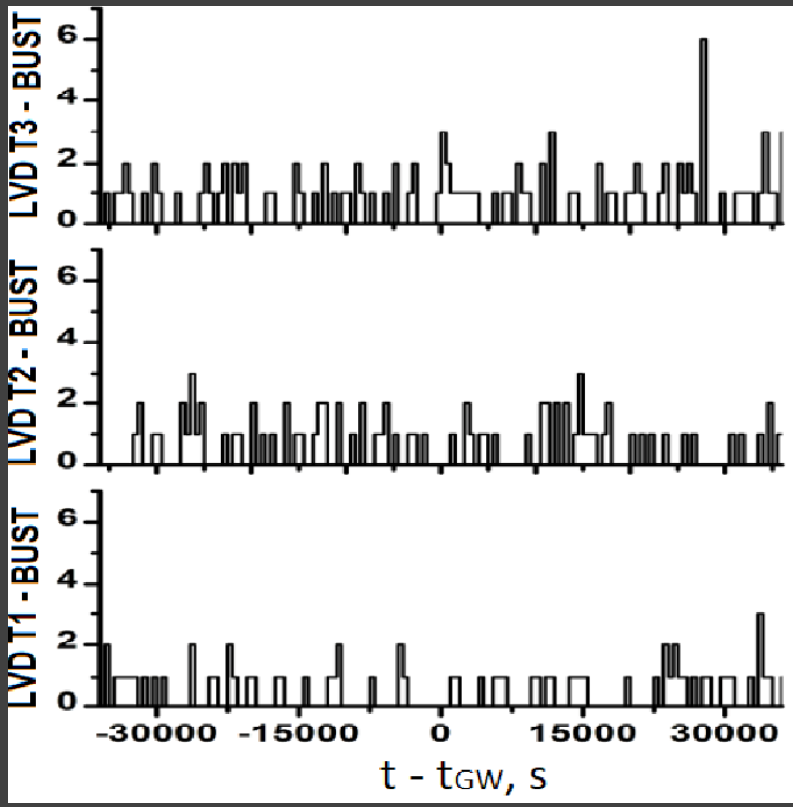


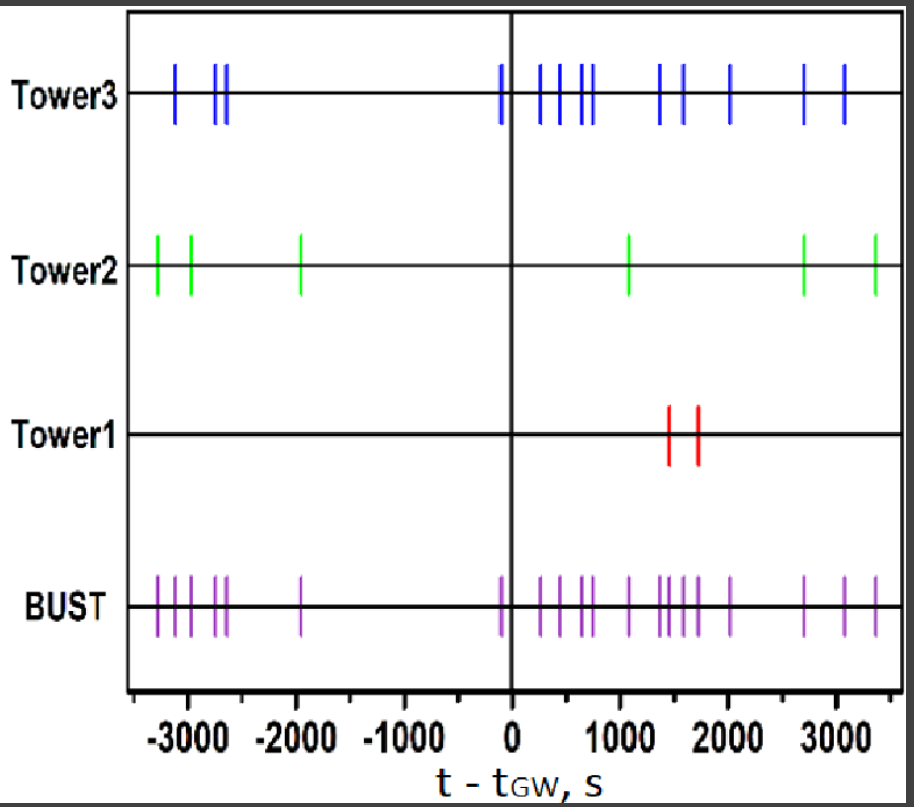
	2013	2014
0	175	167
1	116	130
2	54	46
3	11	16
4	8	5
5	1	1

Number of coincidences per day

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

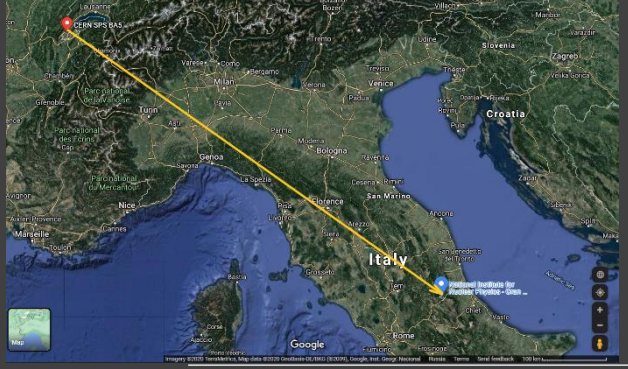
GW 170817



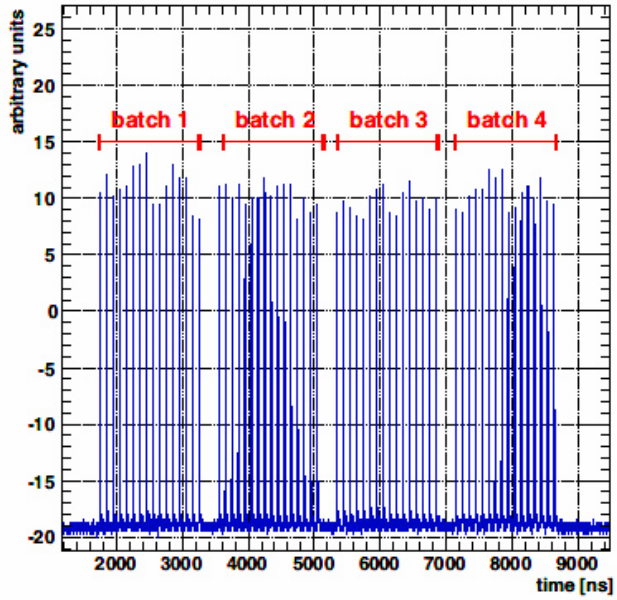


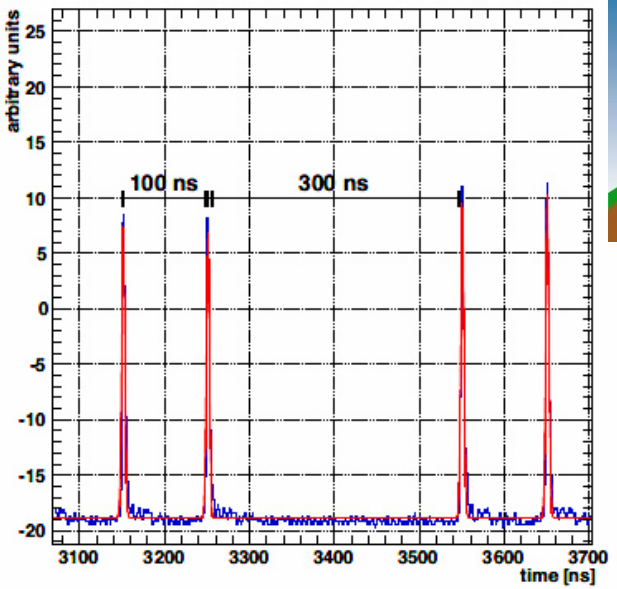
10 days before and after GW 170817

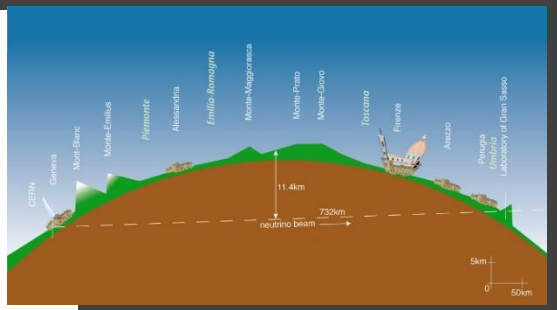
Neutrino velocity



Cern Neutrino to Gran Sasso (CNGS) beam





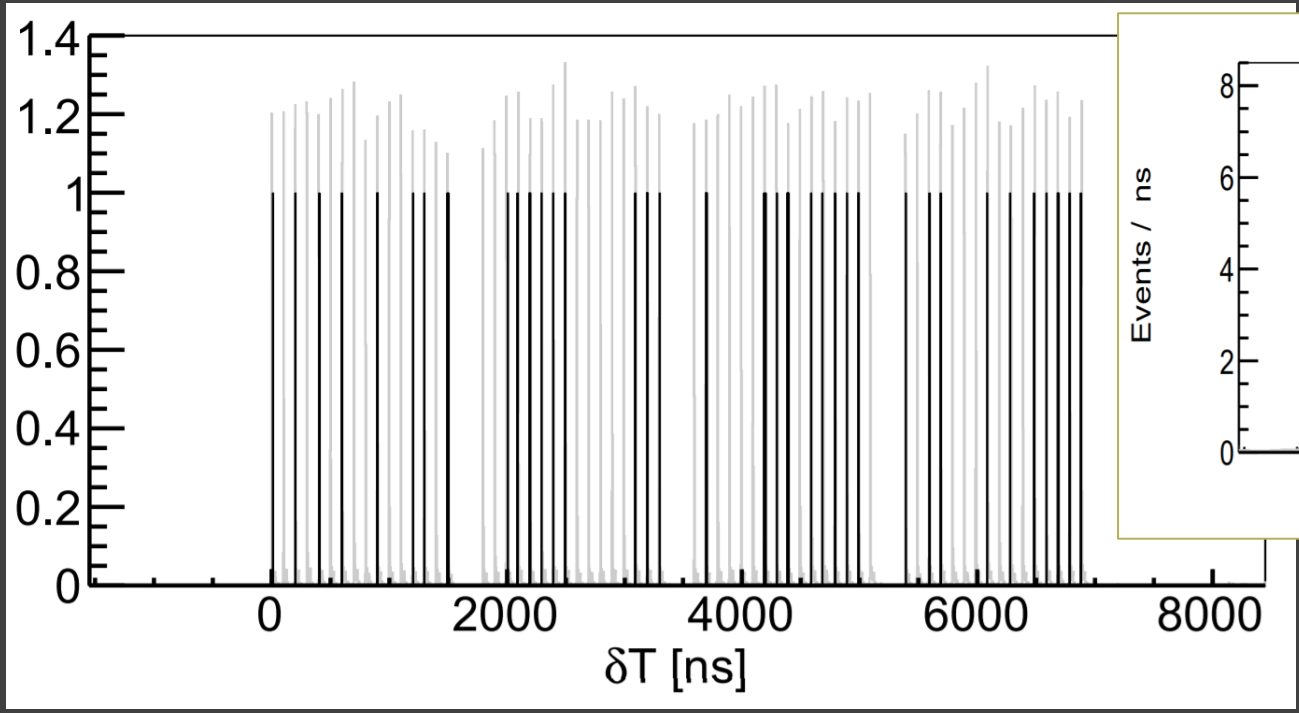


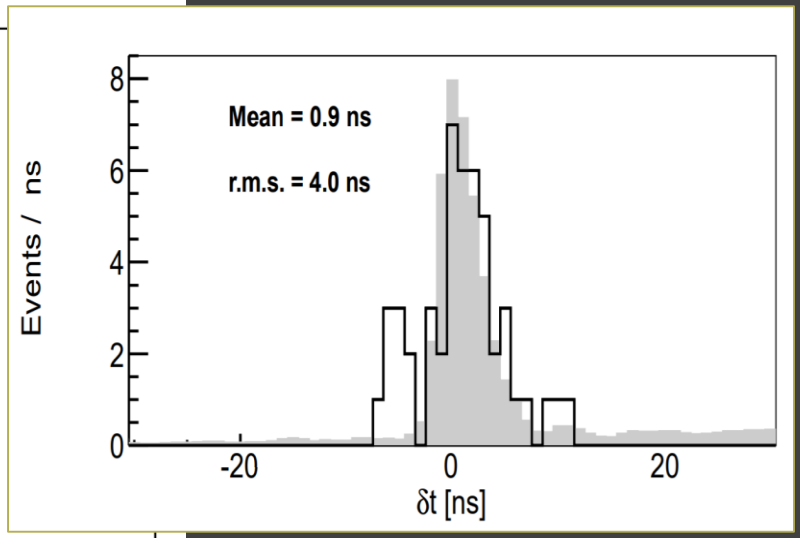
<Ev> = 17 GeV
$L_{CERN\text{-}LVD} \approx 731$ km

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.)

Neutrino velocity





48 events total

δt = -0,3 ± 0.6 (stat.) ± 3.2 (syst.) ns

$-3.3 \times 10^{-6} < (v - c)/c < 3.5 \times 10^{-6}$
$m_{\nu} < 44$ MeV/c^2 (99% confidence level)

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* · *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:

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

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

Thank you!