SN 1987A – *REGISTRATION OF THE NEUTRINO SIGNAL WITH*

BAKSAN,

KAMIOKANDE-II,

IMB

DETECTORS

I.V. Krivosheina,

NIRFI, Nishnij-Novgorod, RUSSIA

BEYOND 2010, CAPE TOWN, SA,

4 February 2010

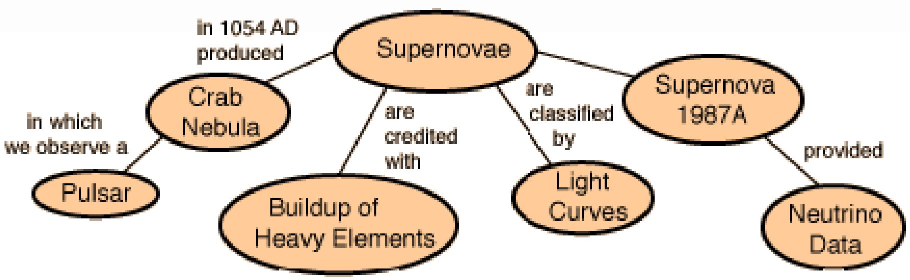
Large Magellanic Cloud, at 7:35 UT February 23, 1987Supernova 1987A

Ian Shelton and Oscar Duhalde at Las Campanas Obs.

On February 23, 1987, a supernova was detected in the Large Magellanic Cloud about 160,000 ight years from Earth. The first supernova to be discovered that year, it was designated SN 1987 A.

The discovery of SN87A was a great opportunity for detailed observation of the dynamics of a supernova.

Unique feature: the star which exploded had been observed and named Sk(Saduleak)–69202. It was a blue supergiant presumed to have a mass of about 20 solar masses



KII

BAKSAN

IMB

11 + 5 + 8 = 24 Neutrinos!!

List of Detectors Which Have Reported Candidates for Neutrinos From SN 1987A

Detector	Fiducial mass (t) (numb. of free protons) of target	Energy Threshold (MeV)	Background rate (sec^{-1})	Number of Events	Durat. of sign. (sec.)	Time (UT)
IMB	6800 (5000) 3.32×10^{32} H_2O	[redacted]				
K II	2140 H_2O 1.42×10^{32}	[redacted]				
Baksan	200 C_9H_{20} 1.87×10^{31}	[redacted]				
Mont Blanc	90 C_9H_{20}	[redacted]				

$\tilde{\nu}_e + p \rightarrow n + e^+$ (absorption)

$\nu_e + e^- \rightarrow \nu_e + e^-$ (elast. scatter.)

$\nu_e(\tilde{\nu}_e) + {}^{16}O \rightarrow {}^{16}F\,({}^{16}N) + e^-\ (e^+)$

$\nu_e(\tilde{\nu}_e) + {}^{12}C \rightarrow {}^{12}N\,({}^{12}B) + e^-\ (e^+)$

for Cherenkov detectors

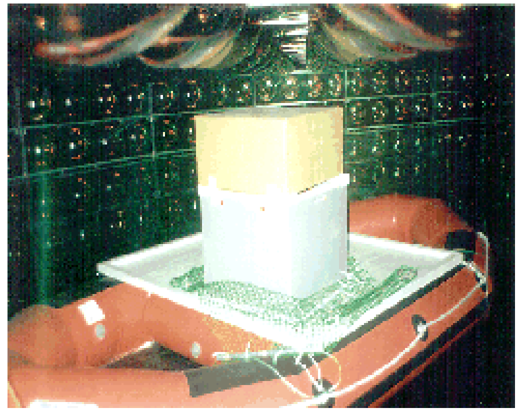
contribution are very small !!

Large Magellanic Cloud, at 7:35 UT February 23, 1987 Supernova 1987A

BAKSAN

Horizontal plane of Baksan Underground Scintillation Observatory (village "Neutrino")

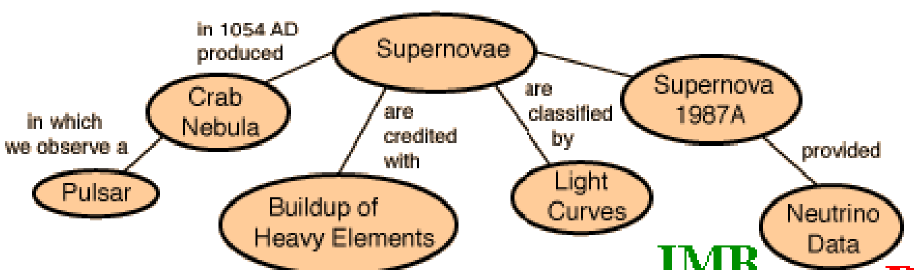
KII



Super–Kamiokande Kamioka Mine, about 200 km north of Tokyo

On February 23, 1987, a supernova was detected in the Large Magellanic Cloud about 160,000 ight years from Earth. The first supernova to be discovered that year, it was designated SN 1987 A.

IMB The detector was built 600 meters underground in the Morton salt mine near Cleveland, Ohio.



KII

IMB

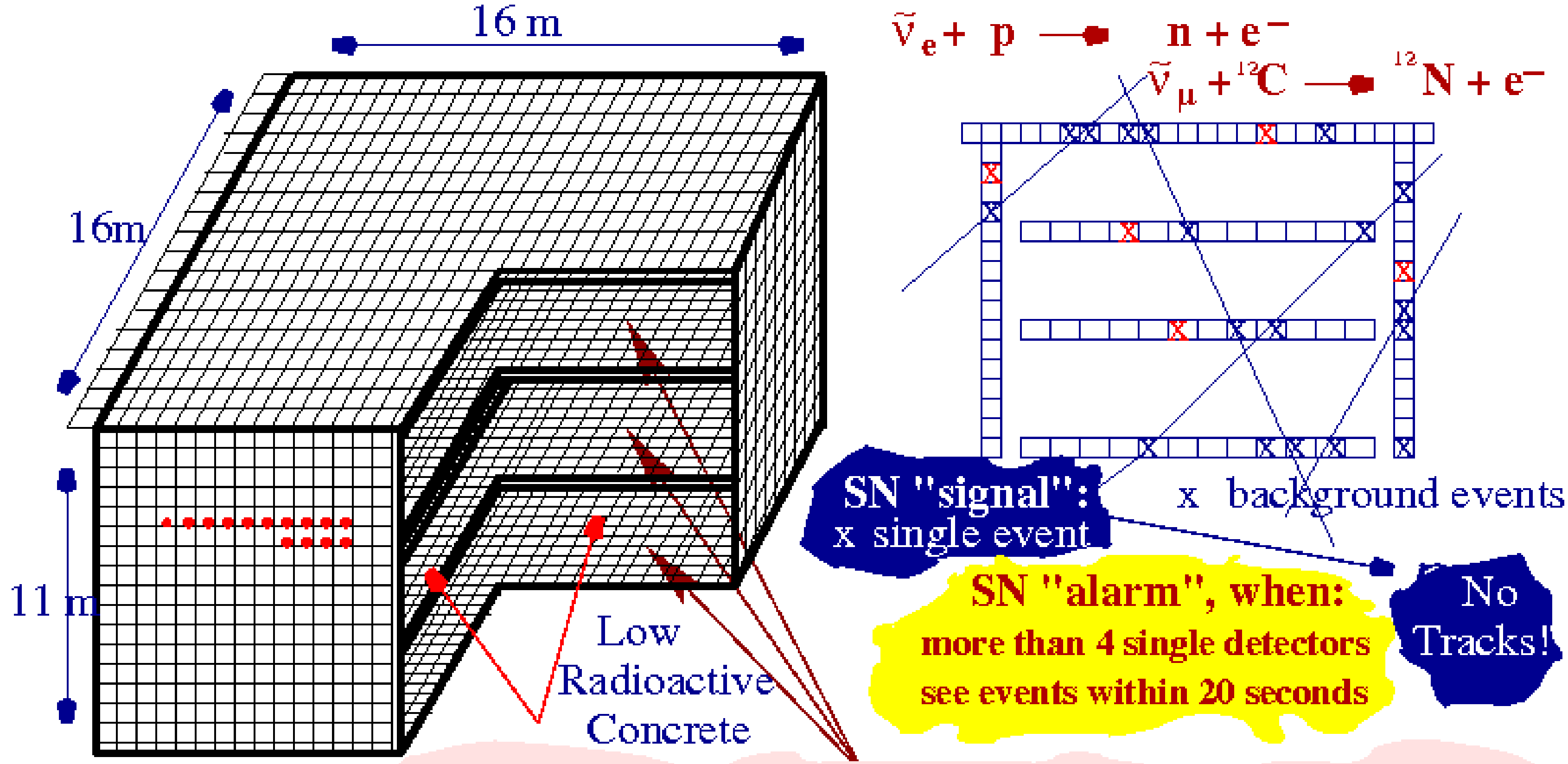
BAKSAN

11 + 5 + 8 = 24 Neutrinos!!

The discovery of SN87A was a great opportunity for detailed observation of the dynamics of a supernova.

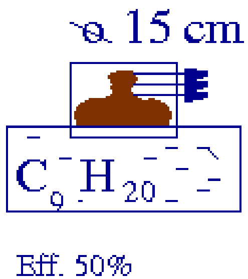
Unique feature: the star which exploded had been observed and named Sk(Saduleak)–69202. It was a blue supergiant presumed to have a mass of about 20 solar masses

The BAKSAN Neutrino Underground Scintillation Telescope



'Fiducial mass' 130 tons – interior 3 plains of telescopes

count. rate= ~ 0.012 sec^{-1}



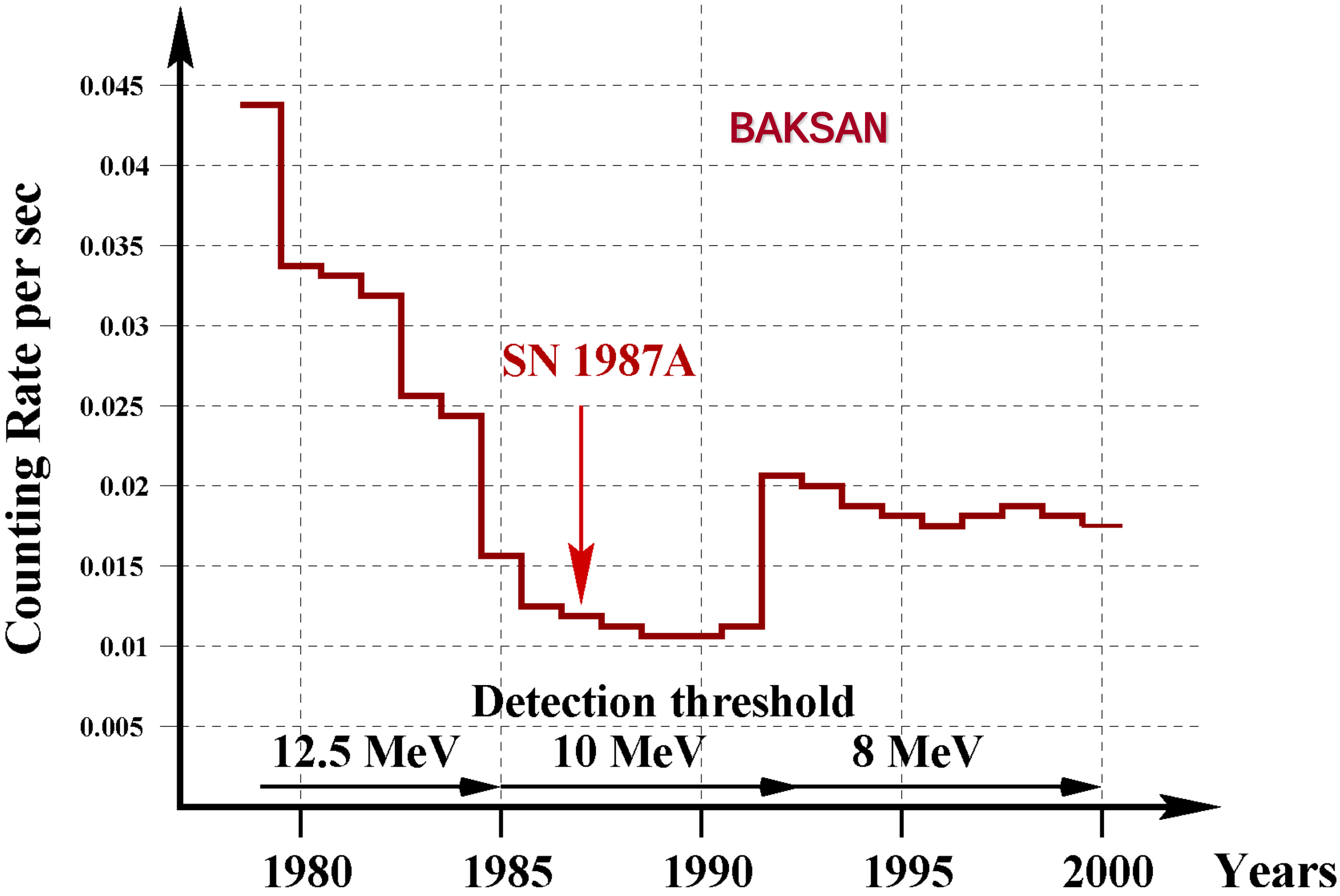
850 m.w.e

E_{th} = 10 MeV

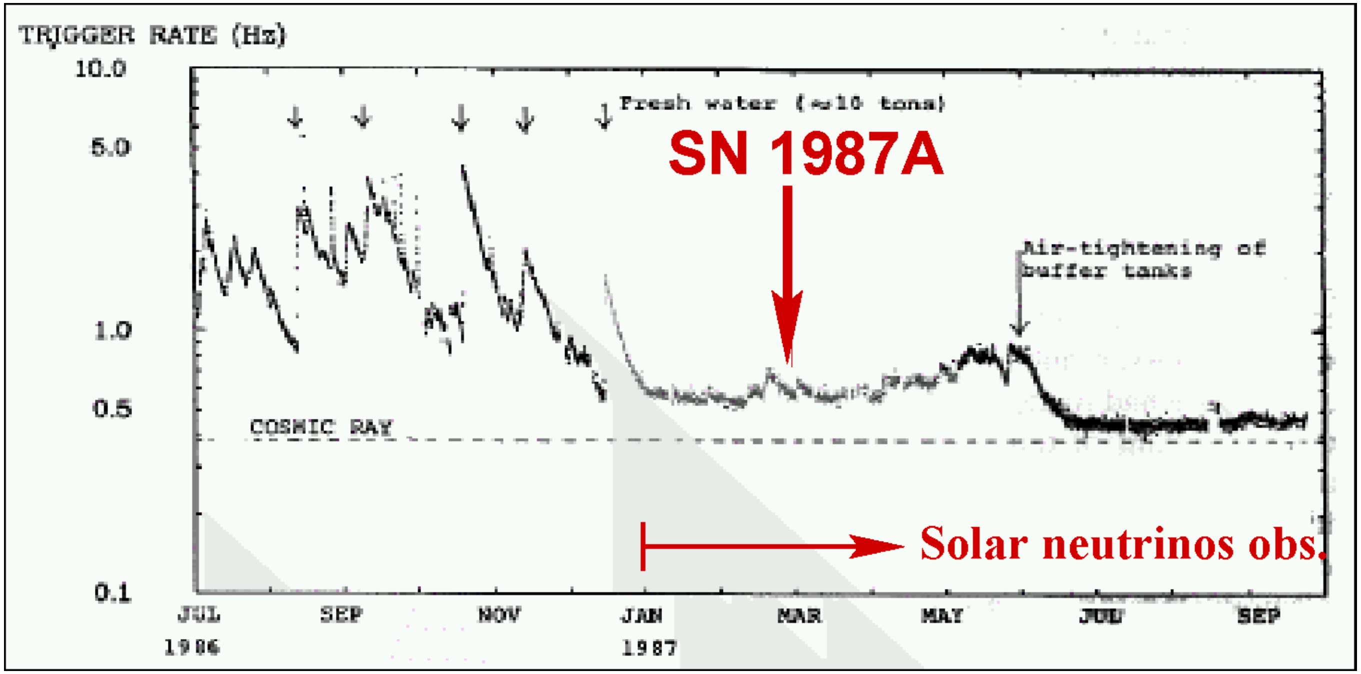
Standard–type
Detector Unit
70x70x30 cm

Total Mass (3150 detectors) – *count. rate= ~ 0.034 sec^{-1}*

330 tons of a liquid organic scintillator

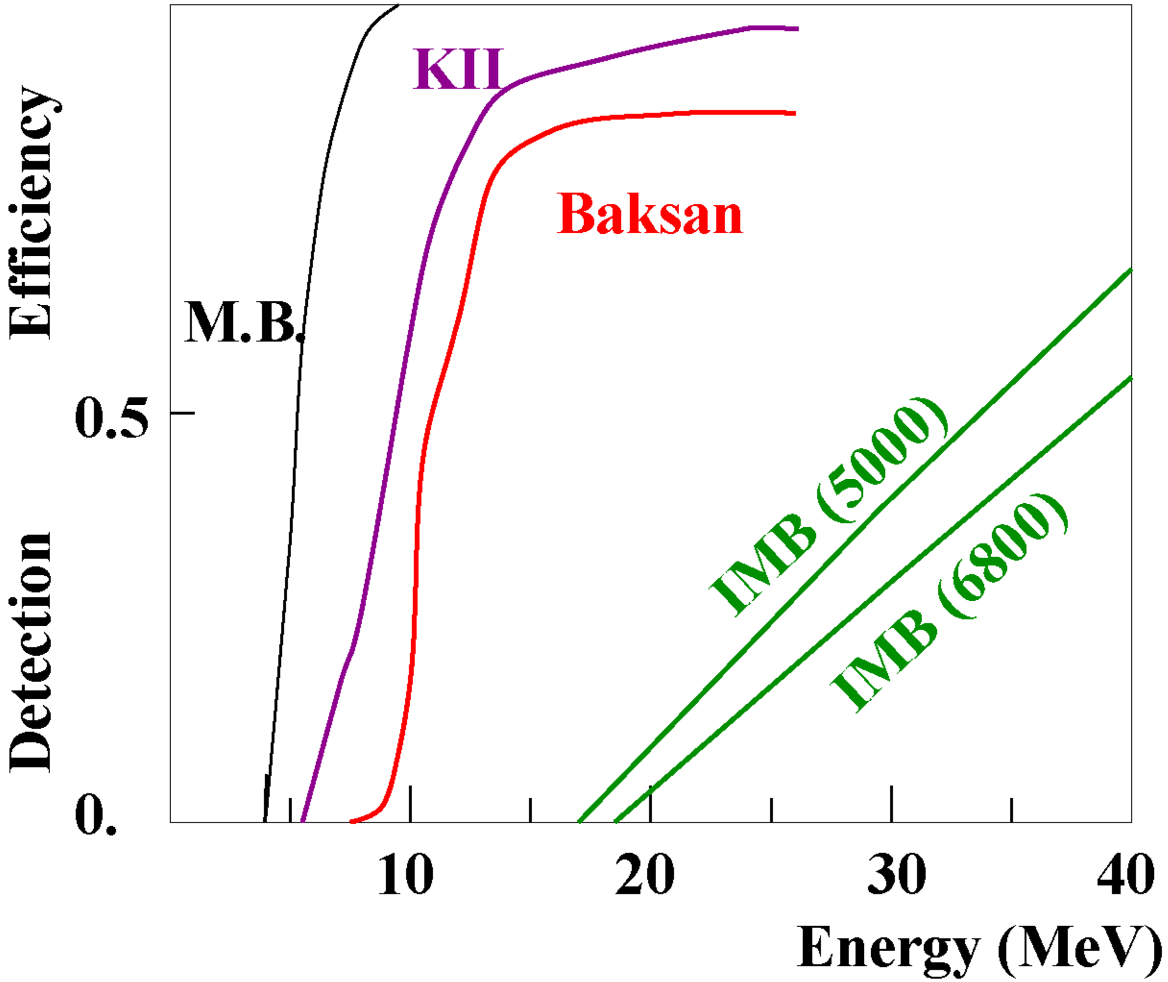


The counting rate of single events of the 1200 detectors in the tree internal planes of the telescope (the target mass is 130t) during the period 1980-2000. The improvement with time is shown ***(from Zh. Eksp. Teor. Fiz. 95 (2002) 10-16).***



The background development of the KAMIOKANDE II detector.

It was inmproved ***only after the SN87A signal***, by installing isolation structures from the mine air both in the 3000 ton tank and the water-purification system, and kept under control since end of May 1987.



Comparison of trigger efficiencies of all SN87A detectors.

IVK, Int. J. Mod. Phys. I13 (2004) 2085-2105, T.J. Loredo, D.Q. Lamb PRD (2002) 063002, E.N. Alexeev, L.N. Alexeeva, IVK, V. Volchenko, PLB 205 (1988) 209-214

List of Detectors Which Have Reported Candidates for Neutrinos From SN 1987A

Detector	Fiducial mass (t) (numb. of free protons) of target	Energy Threshold (MeV)	Background rate (sec^{-1})	Number of Events	Durat. of sign. (sec.)	Time (UT)
IMB	6800 (5000) 3.32×10^{32} H_2O	35	0.077	8	6.0	7.35
K II	2140 H_2O 1.42×10^{32}	8.5	0.022	11	12.5	7.35
Baksan	200 C_9H_{20} 1.87×10^{31}	10	0.034	5	9.1	7.35
Mont Blanc	90 C_9H_{20}	5.5	0.012	5	7.0	2:52

$\tilde{\nu}_e + p \rightarrow n + e^+$ (absorption)

$\nu_e + e^- \rightarrow \nu_e + e^-$ (elast. scatter.)

for Cherenkov detectors

$\nu_e(\tilde{\nu}_e) + {}^{16}O \rightarrow {}^{16}F\ ({}^{16}N) + e^-\ (e^+)$

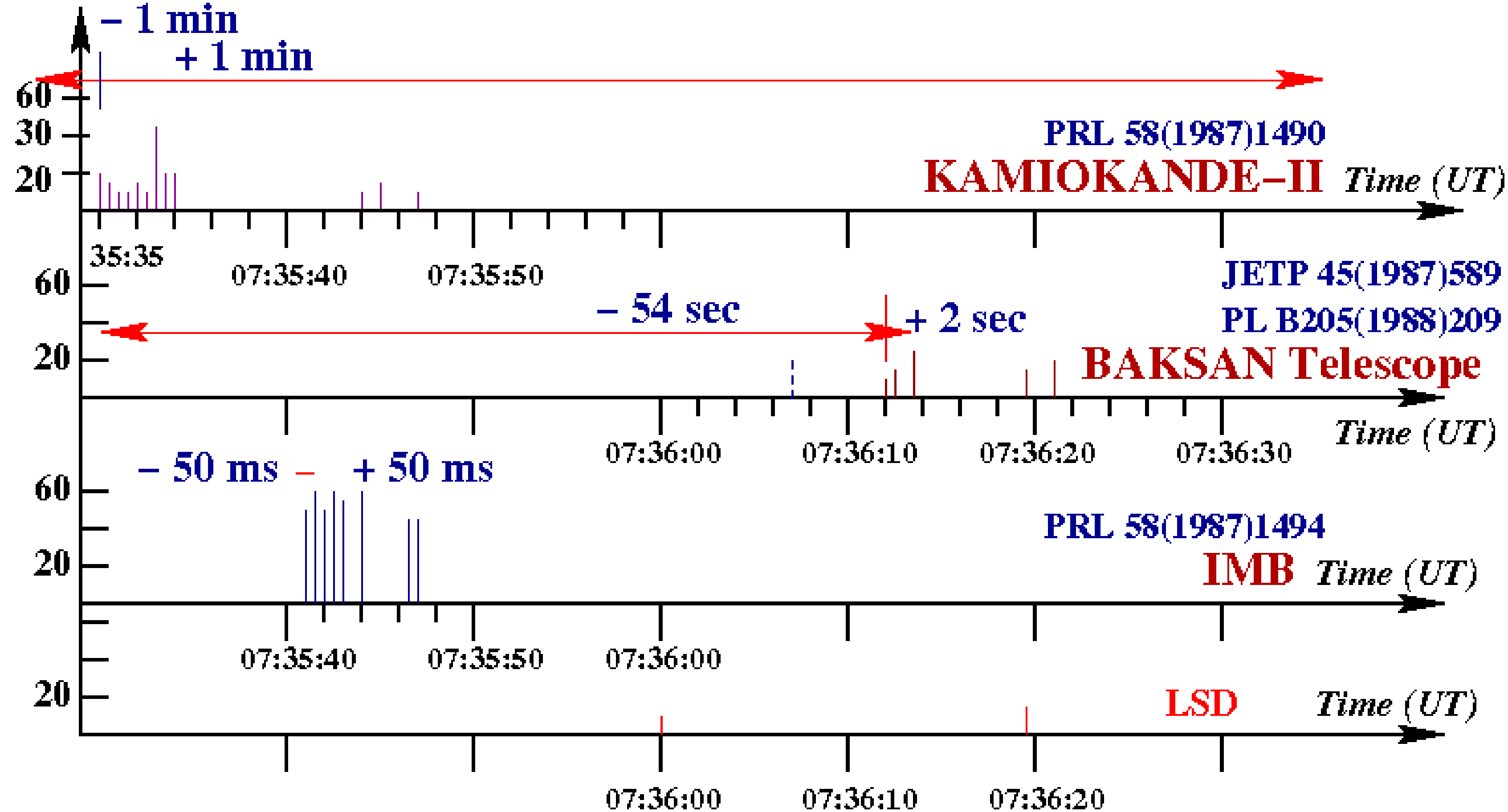
$\nu_e(\tilde{\nu}_e) + {}^{12}C \rightarrow {}^{12}N\ ({}^{12}B) + e^-\ (e^+)$

contribution are very small !!

SUPERNOVAE   SN 1987 A

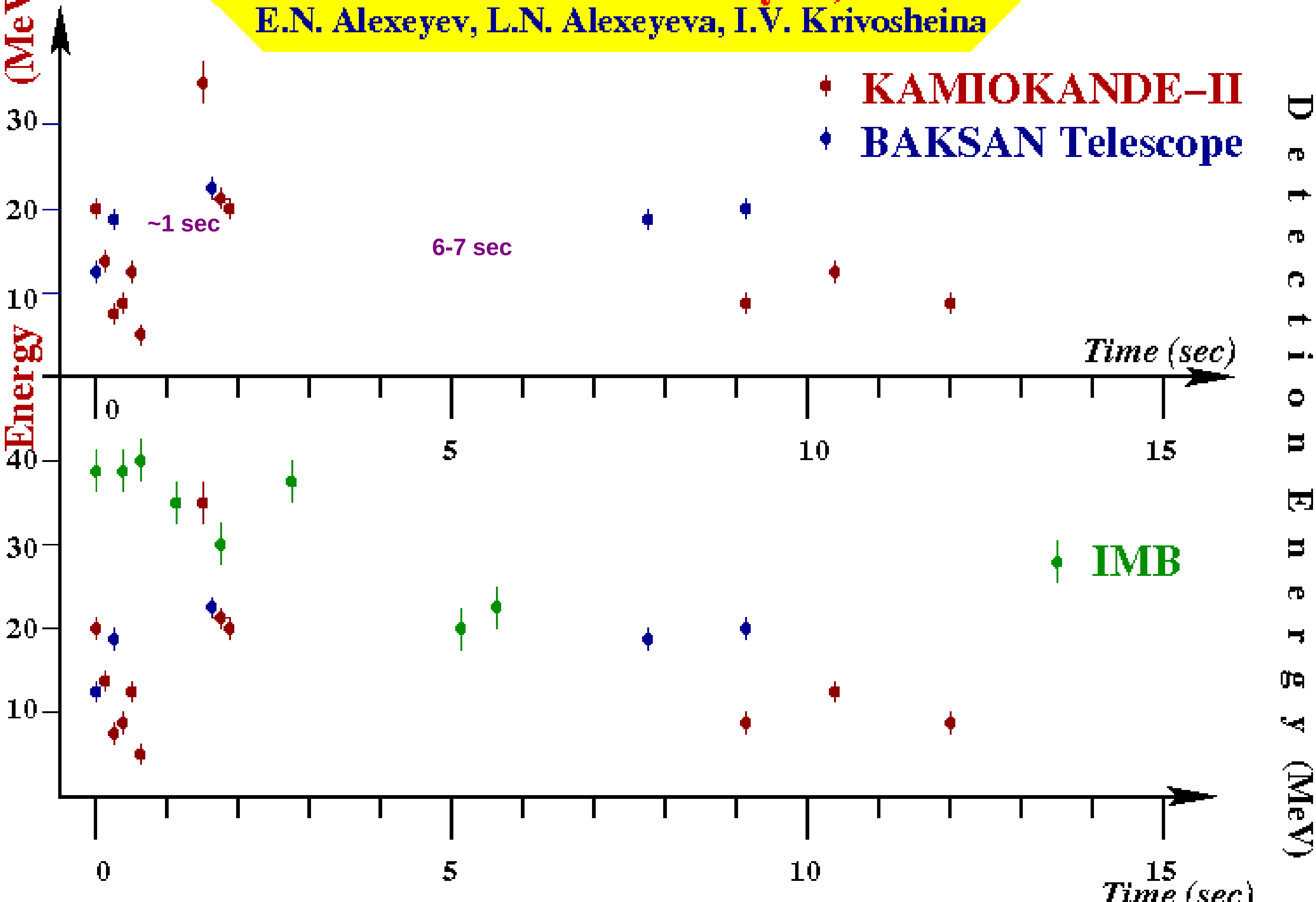
The time sequences of events detected by KAMIOKANDE–II, Baksan telescope, IMB and LSD detectors at 07:35 UT on February 23, 1987.

E.N. Alexeyev, L.N. Alexeyeva, I.V. Krivosheina and V.I. Volchenko
JETP Letters May 25 1987, Vol. 45 pp. 589–592
Physics Letters B 205 (1988) 209–214



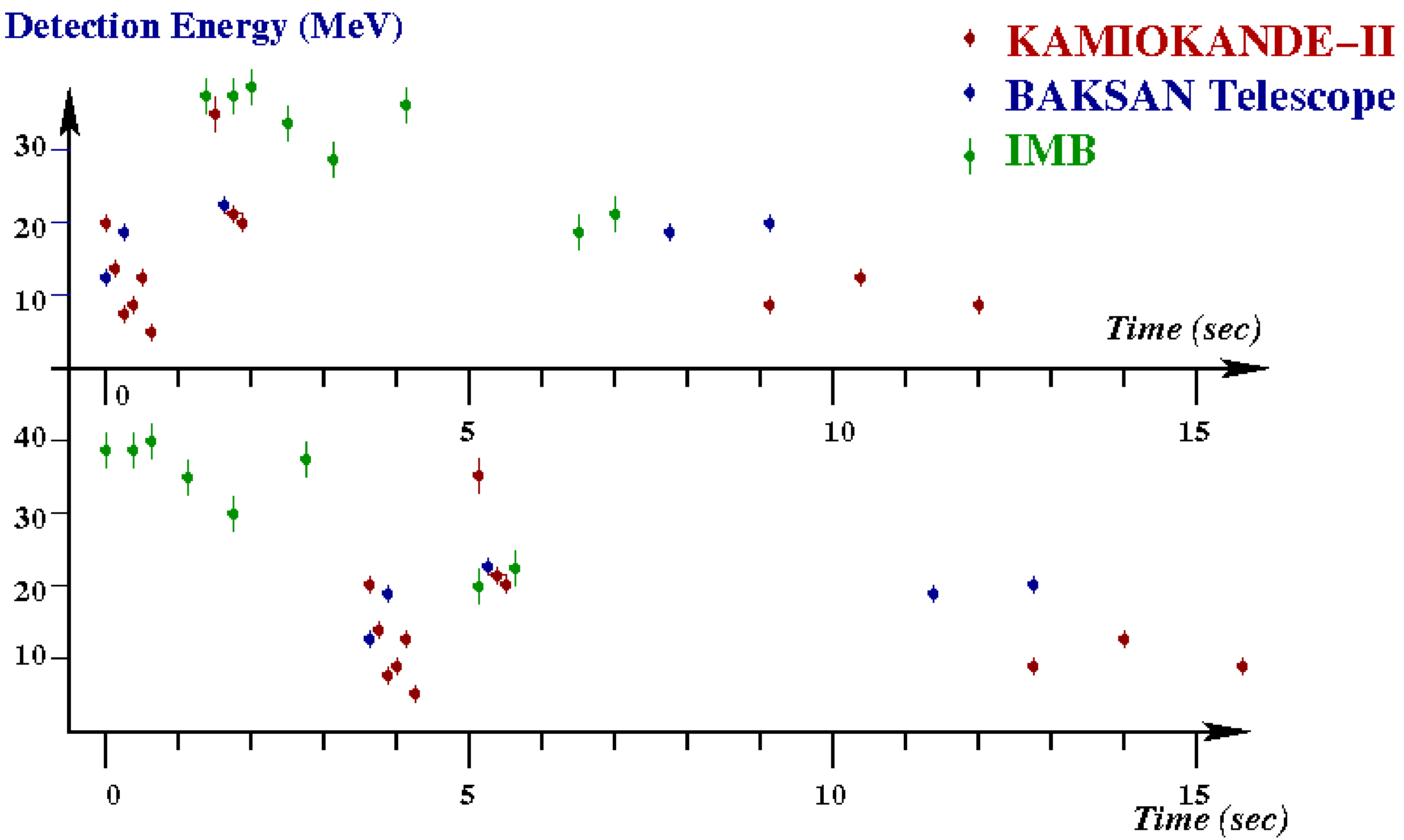
Time profiles of the events recorded by KII, Baksan telescope and by all three detectors setting the time equal for the first events of each detector at 07:35 UT on February 23, 1987.

E.N. Alexeyev, L.N. Alexeyeva, I.V. Krivosheina



Time profiles of the events recordede by KII, Baksan telescope setting zero time to be the time of the first events for Baksan and KII detectors at 07:35 UT on 23.02.1987, and assuming coincidence of the first IMB signal with the first high energy signal of KII

E.N. Alexeyev, L.N. Alexeyeva, I.V. Krivosheina



The *most recent* analysis of the temporal structure of the neutrino signal from the SN 1987A was done in 2001 (used a Bayesian analysis – is very adequate to work with very low statistics.

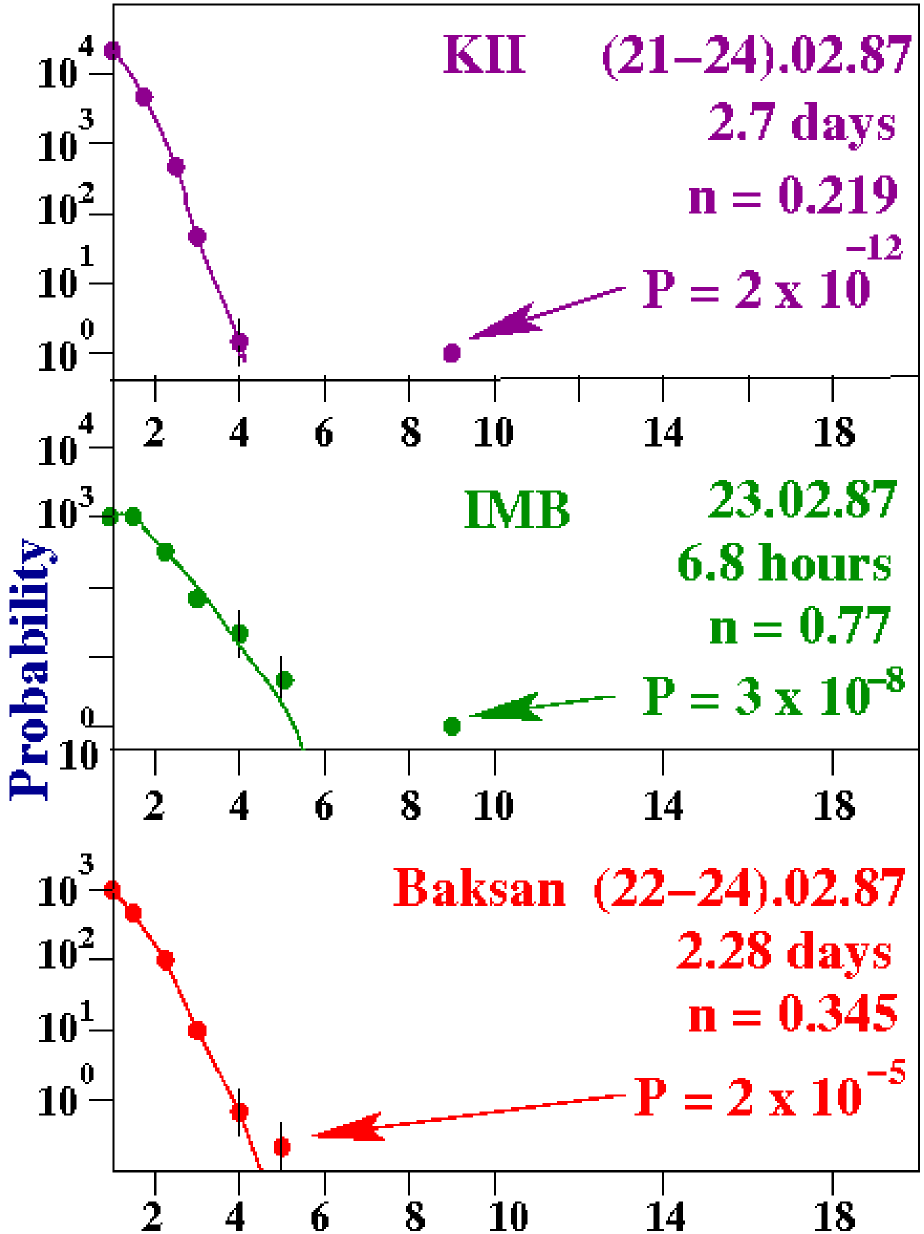
T.J. Loredo, D.Q. Lamb PRD (2002) 063002

***This analysisi shows*:**

".. A *strong* evidence *for two components in the neutrino signal* …" on the basis of an analysis of the energies and arrival times of the neutrinos from SN 87A detected by KII, IMB and Baksan neutrino scint. telescopes.

For the first time after 17 years of explosion of the SN 87A

" .. The Baksan neutrino scintillation telescope data are fully consistent with the KII and IMB data .."



E.N. Alexeyev, L.N. Alexeyeva, I.V. Krivosheina

Eur. Int. Conf. Cosm. Rays Hungary, 1988

XX IAU General Assembly, August 1988, Baltimore, USA

Poisson distribution for events within 10 sec interval detected in the period surrounding the time of Supernova.

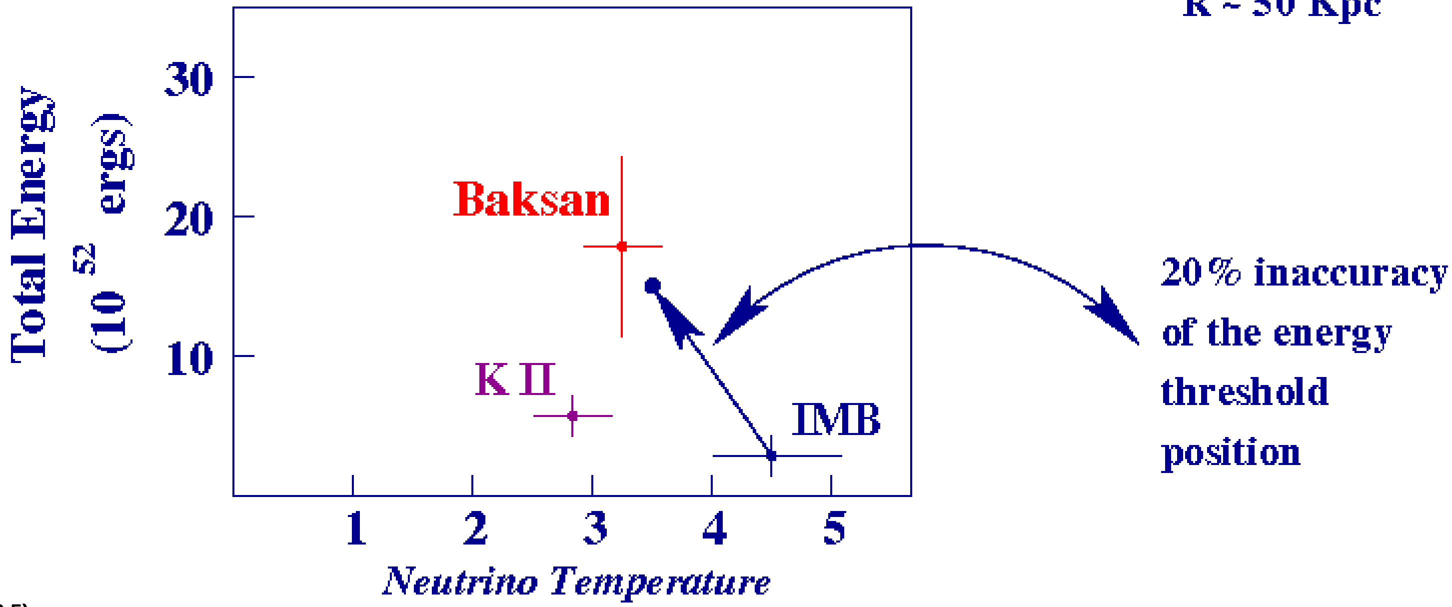
n is the average of the background c.r. per second

(this means one such event per ~ 20 years)

Main Parameters of the Neutrino Signal from SN 1987A

Detector	Average detected energy (MeV)	Neutrino temper. (MeV)	$E_\nu * 10^{52}$ (ergs)
KAMIOKANDE	16.7 ± 1.1	2.8 ± 0.3	5.8 ± 1.8
Baksan	19.4 ± 1.7	3.3 ± 0.4	18.6 ± 8.5
IMB (5000 t)	33.8 ± 2.9	4.5 ± 0.7	2.9 ± 1.1
IMB (6800 t)	33.2 ± 2.5	4.3 ± 0.6	3.2 ± 1.1

R ~ 50 Kpc



KII - 2140 tons,

680 tons (factor of 2.5)

The distance to the SN87A 50Kpc, the neutrino spectrum has a Fermi-Dirac shape

CONCLUSIONS

- The neutrino signal from SN 1987A was observed. There are *24 events in three detectors* recorded at 7:25 UT on February 23, 1987.
- The average derived characteristics of the burst are consistent with the general theoretical picture of SN explosions: the evolution of the neutrino emission is approximately described as an exponentially decaying signal with characteristic time ~ 5 seconds;

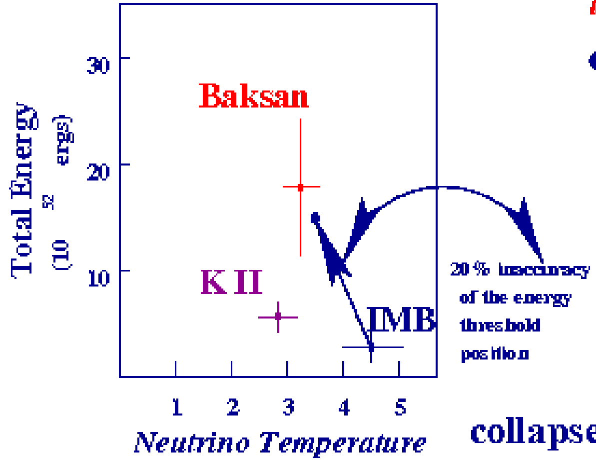
the total duration of the neutrino signal is ~ 20 sec

the detected energies of the events are consistent with thermal neutrino spectrum and the effective neutrino temperature of 3–5 MeV (if a single temper. spectrum is supposed)

the total energy of the neutrino emission is ~ 3 10^{53} ergs

the residue of Supernova is most probably a neutron star with a mass of ~ 1.4 $M_\odot$

- The temporal distribution of the KK–II and BAKSAN events is in favour of a *three–bunch shape of the neutrino signal*



- The propeties of the IMB signal are somewhat distinct from those of the KK–II one and the Baksan one.
- Based upon the Baksan data obtaining during *17.6 years from (19.75 years of calendar time)* *(since 30.06.1980)*

No signal, except SN 1987A in the LMA, was detected. The upper limit on the frequency of collapses in the Galaxy *< 0.13 yr^{-1} (90% c.l.)*

The mean time inerval between the expected Galactic events is > 7.7 years (90% c.l.)

(E.N. Alexeyev, L.N. Alexeyeva, JETP 95 (2002) 5–10)

What kind of criteria should be fulfilled by an experiment searching for supernova explosion?

1. A "Supernova" detector ***should be able*** to detect the ν, $\bar{\nu}$, as well as all types of neutrinos ν_e, ν_μ, ν_τ.

2. The time distribution of the events (neutrinos-antineutrinos) and ***perfect absolute time***.

3. The energy of each event.

4. All detectors *must* have a 'low' energy threshold **(not bigger than 10 MeV).**

5. The detector *must* be located in a deep underground laboratory, to reduce the background from the muons.

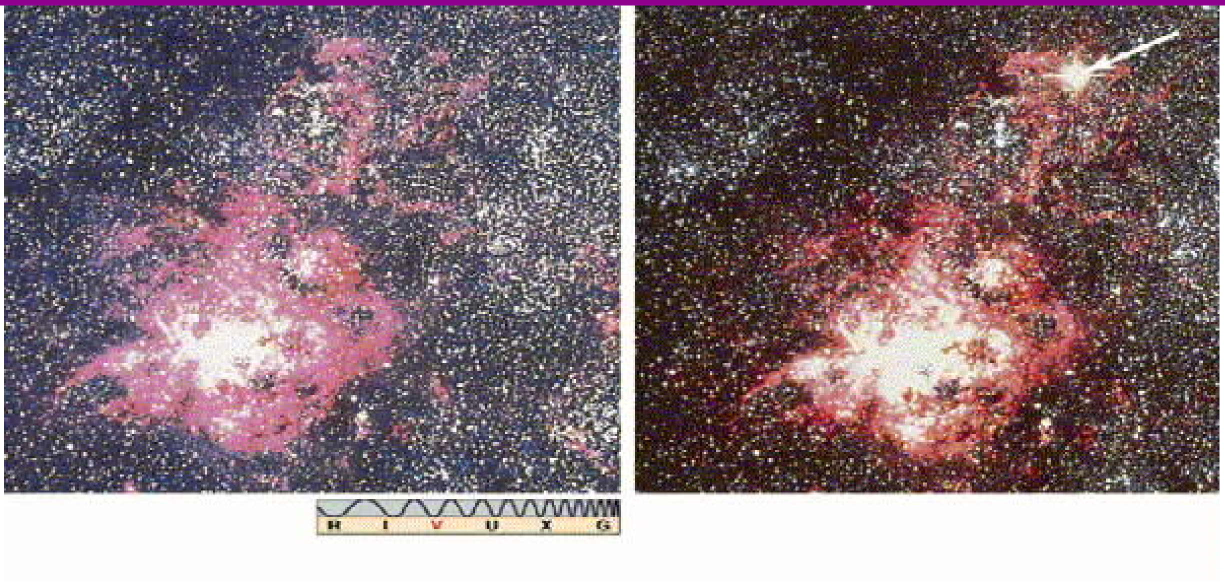
6. The detector must have a ***big fiducial*** mass, to be able to see a neutrino signal from our Galaxy or from the Universe with sufficiently good statistics.

7. The detector **must run permanently and stable before and after a SN signal**.

CONCLUSIONS

- **The neutrino signal from SN 1987A was observed. There are *24 events in three detectors* recorded at 7:25 UT on February 23, 1987.**

The observation of the NEUTRINO SIGNAL with the expected general characteristics is the great success of the theory and the experiment.



The time sequences of events detected by the LSD and the Baksan telescope at 02:52 UT on February 23, 1987.