"Наблюдение нейтринного излучения от SN 1987A на LSD"

Сааведра Оскар
(Туринский университет, Италия).

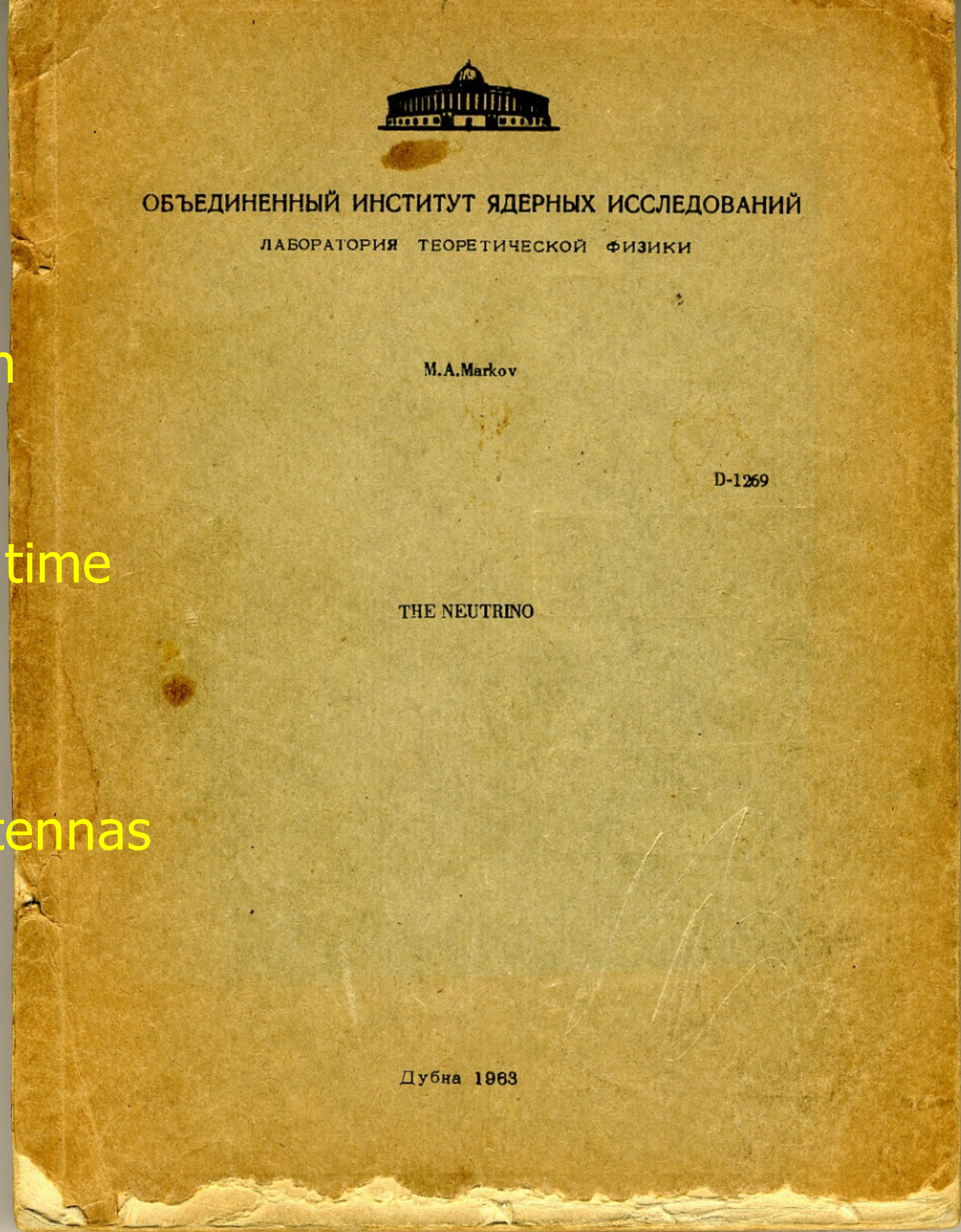
I am very honoured to have the opportunity to give this talk in this famous Academy.

Thank you very much to Academician Victor Mateev, Director of the INR of the Russian Academy of Science, for the award that may be I didn't deserve.

LAY OUT

1.- LSD at Mt. Blanc
2.- On-line Burst detection
by LSD at Mt. Blanc
3.- IMB, K-II and BST
SN neutrino detection time
4.- Correllations between
LSD - K-II and BST
5.- Correllations between
LSD –IMB and GW antennas

Conclusions


ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

M.A.Markov

D-1269

THE NEUTRINO

Дубна 1963

Liquid Scintillator Detector (LSD)

Istituto di Cosmogeofisica del CNR,
Istituto Di Fisica generale
Universita' di Torino, Italy

M.Aglietta,
G.Badino,
G.Bologna,
C.Castagnoli,
A.Castellina,
W.Fulgione,
P.Galeotti,
O.Saavedra,
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The Institute for Nuclear Research
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V.L.Dadykin,
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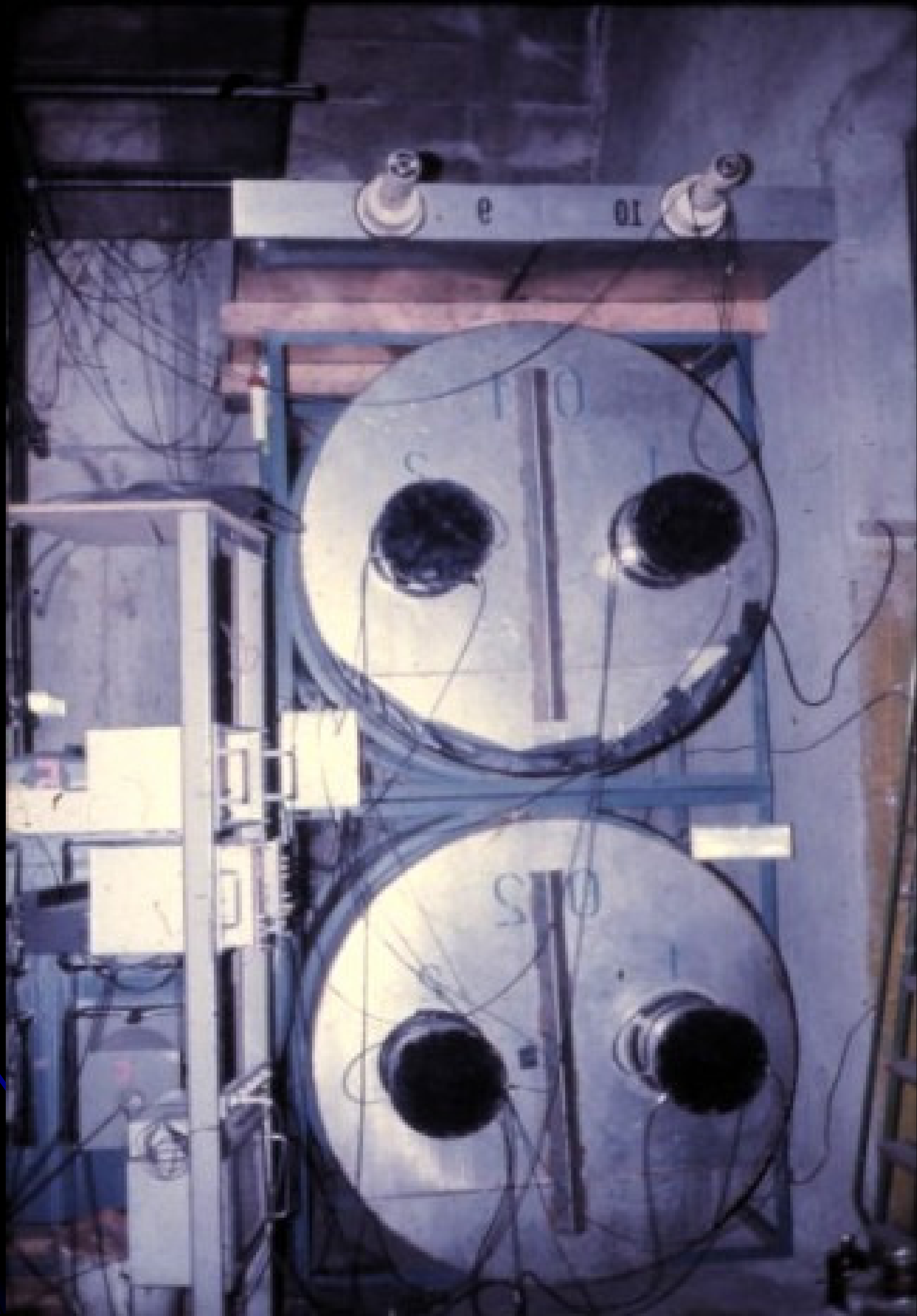
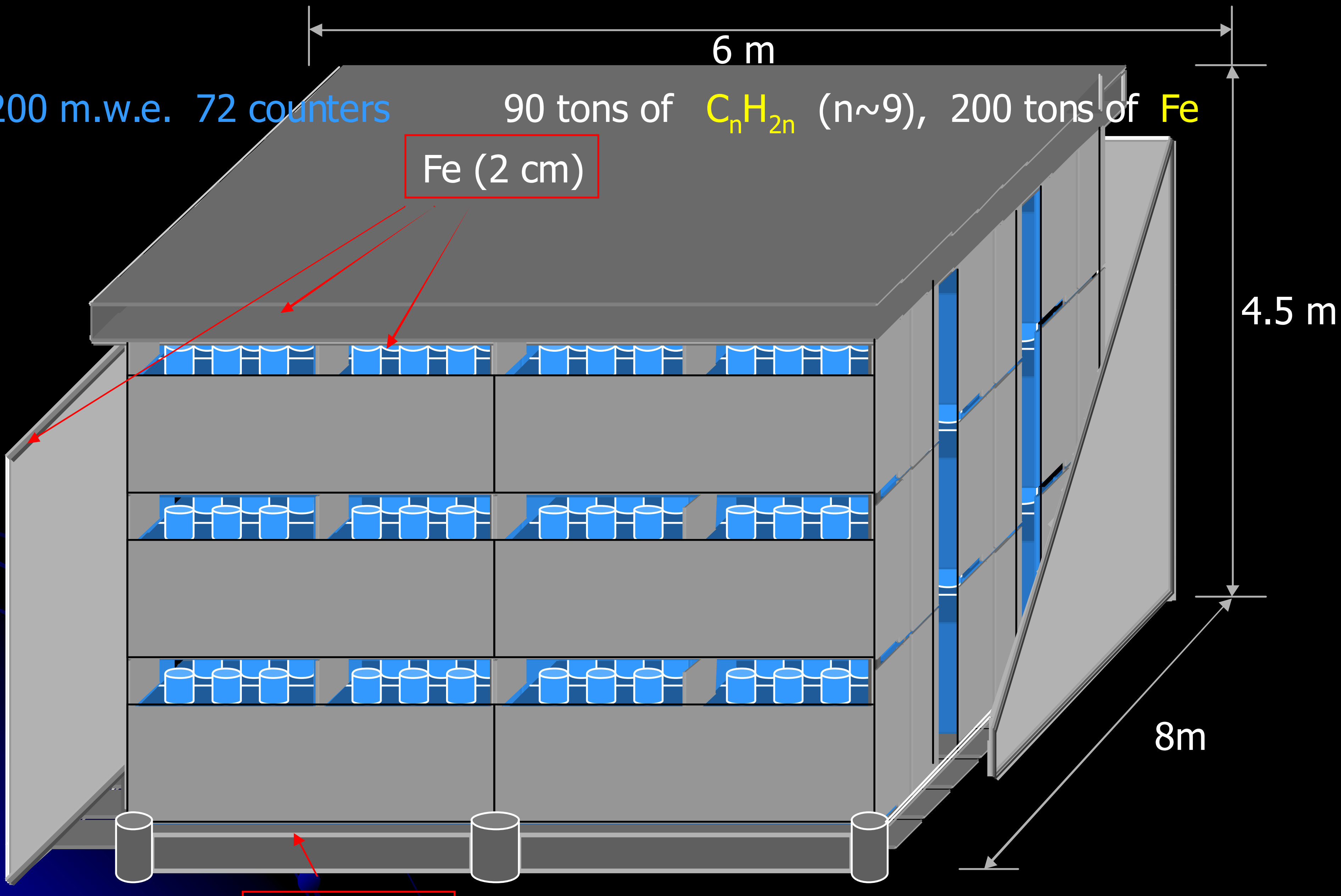
P.V.kortchaguin,
V.B. Kortchaguin,
A.S. Malguin,
V.G.Ryassny,
O.G. Ryazhskaya,
V.P.Talochkin,
G.T.Zatsepin
V.F.Yakushev



Liquid Scintillator Detector (LSD)

H=5200 m.w.e. 72 counters

90 tons of C_nH_{2n} (n~9), 200 tons of Fe



General view of LSD

Detection mode

Detection of e^+ from the reaction $\tilde{\nu}_e + p \rightarrow e^+ + n$

that has a large $\tilde{\nu}_e$-p cross section.

$$\sigma_{\tilde{\nu}_e p} \sim 9.3 E^2_{e^+} \cdot 10^{-44} cм^2$$

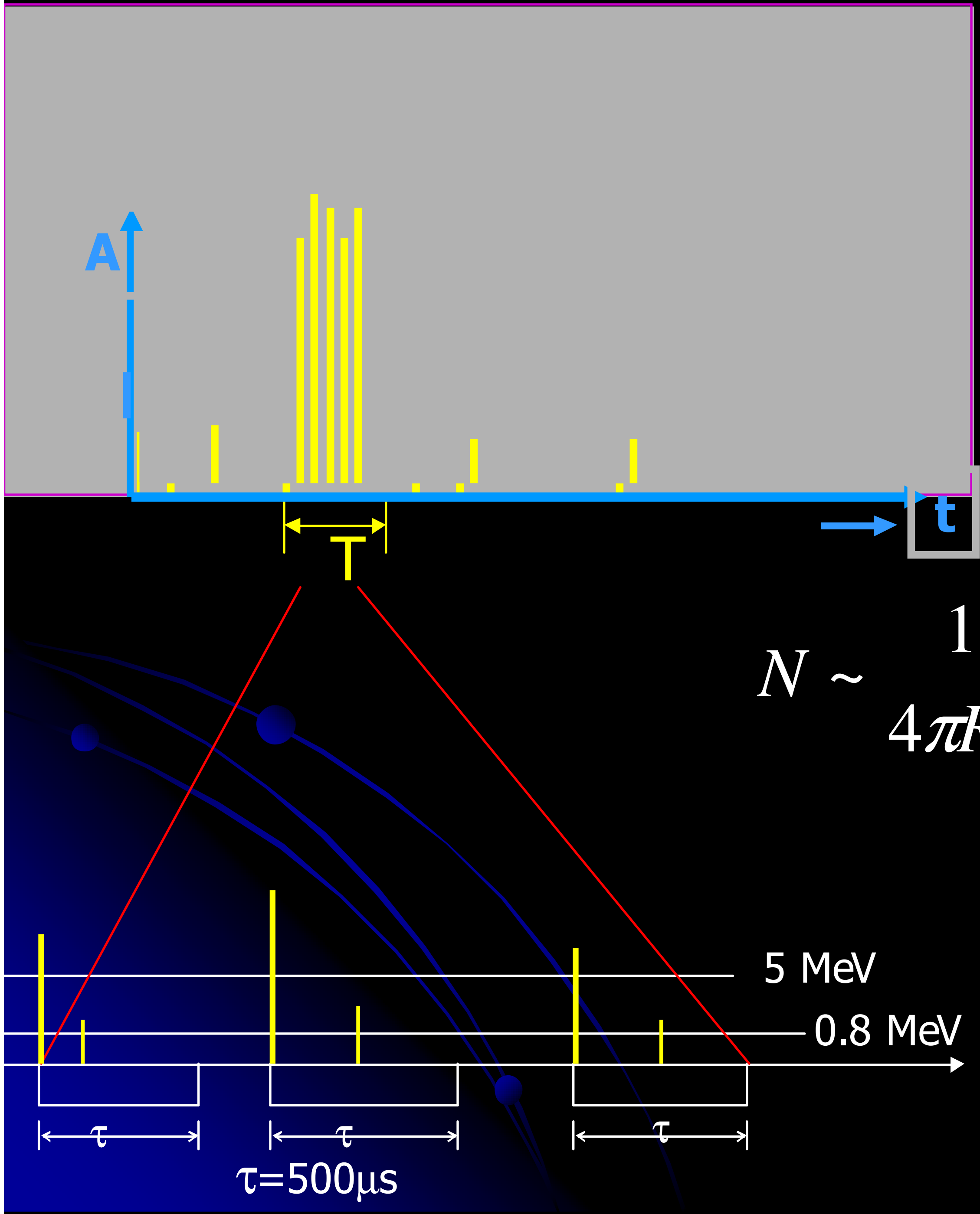
$$E_{e^+} >> 0.5\ MeV$$

It was shown for the first time by G.T.Zatsepin, O.G.Ryazhskaya, A.E.Chudakov (1973):

$$n + p \rightarrow d + \gamma \quad E_\gamma = 2.2\ MeV$$

with τ~180 – 200 μs.

How can the neutrino burst be identified ?



The detection of the burst of N impulses in short time interval T

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

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

If R ~ 10 kpc

N_{int} ~ 50 in LSD
Δt ~ 5-20 sec
E_{e^+} < 50 MeV

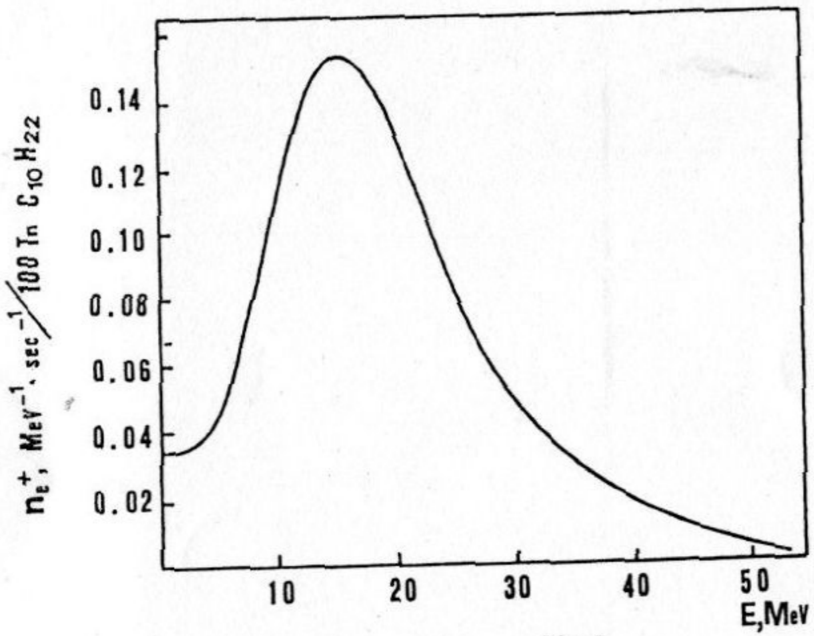


Fig.3

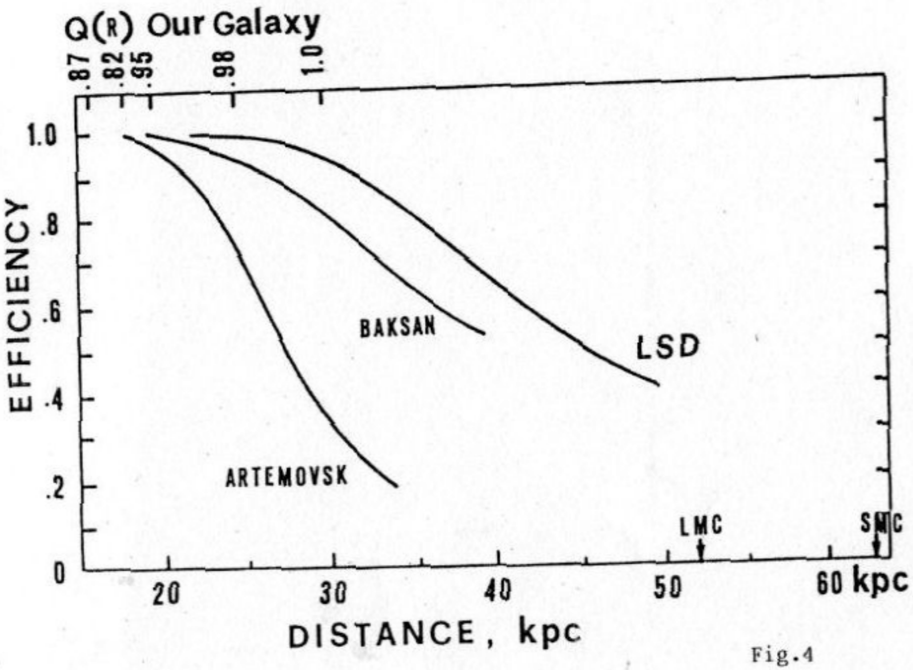


Fig.4

O. SAAVEDRA

Finally, if the collapse occurs within our Galaxy, a large ammount of information on the dynamics of the collapse and on the physical conditions inside the pre-supernova core can be obtained by observing not only the $\bar{\nu}_e$ through reaction (1), but also the ν_e through the elastic scattering reaction $\nu_e + e^- \rightarrow \nu_e + e^-$, which however produces a lower number of interactions in the detector. The signature of the electron neutrinos is given in LSD by pulses above the high energy threshold of 7 MeV, without any low energy delayed pulse. In this way, since ν_e are emitted as early as the neutronization stage of the collapse, the initial phases of the development of a collapsing star can be study.

4. Solar neutrinos

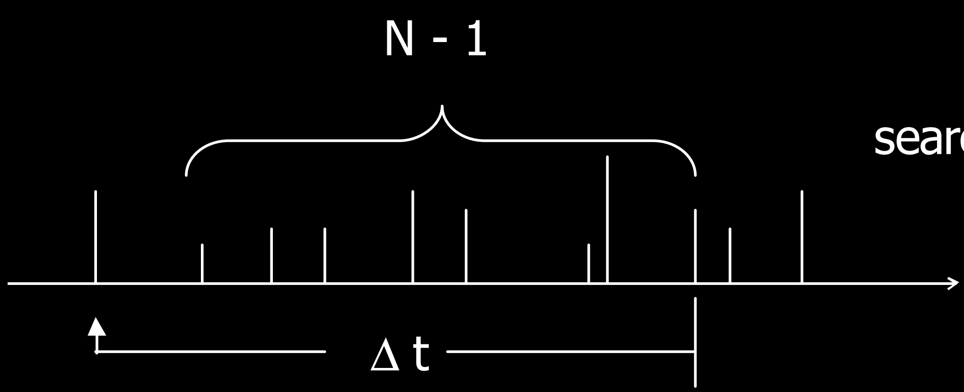
Since in our apparatus the local radioactivity background from the surrounding rock has been reduced to very low counting rates, we are checking the possibility to detect high energy solar neutrinos from the ^{10}B decay in the Sun, through the elastic scattering reaction with the electrons of our detector.

By using the present limit flux of solar neutrinos observed in the Brookhaven detector, and taking into account that the energy threshold in our apparatus can be set at 5 MeV, the number of detectable electrons from solar neutrinos is ~ 0.3/day.

5. Atmospheric neutrinos

At low energy range, $10 \lesssim E_\nu \lesssim 700$ MeV, no experimental information is at present available for the atmospheric neutrino spectrum; also the theoretical predictions are not well defined in this region, even if some calculations have been recently made for energies $\gtrsim 200$ MeV to stimate the neutrino background in proton decay experiments in underground laboratories. However, new efforts are in progress, Gaisser[7], to predict the neutrino spectrum at low energies.

With our LSD experiment we intend to directly measure the $\bar{\nu}_e$ atmospheric neutrinos above an energy threshold of $\gtrsim 10$ MeV through reaction (1). By measuring inside the fiducial volume of LSD both the energy of the contained e^+ and the associate γ-pulse from neutron capture, we'll obtain a direct experimental measure of the $\bar{\nu}_e$ atmospheric spectrum, with a very clear signature that makes such events easily distinguishable from any other type of neutrino interactions. At a threshold of 10 MeV, the total number of atmospheric neutrino interactions has been estimated to be of the order of a few tens per year.



ON-LINE:

search for cluster of pulses in real-time

$N > 2$

$1\ \text{ms} < \Delta t < 600\ \text{sec}$

$$F_{imit} = f \sum_{n=N-1}^{\infty} P(n, \Delta t) = f \sum_{n=N-1}^{\infty} \frac{e^{-f\Delta t}(f\Delta t)^n}{n!}$$

if F_{imit} < 1/10 day ⟶ **print-out**

Conditions:
- Only 1 pulse/N_{tank}
- E < 60 MeV

OFF-LINE

Avoid some noise, uniform distribution, scape muons, etc } < 0.1 %

Phase A

On-line Burst detection by LSD at Mt. Blanc

February 23, 1987

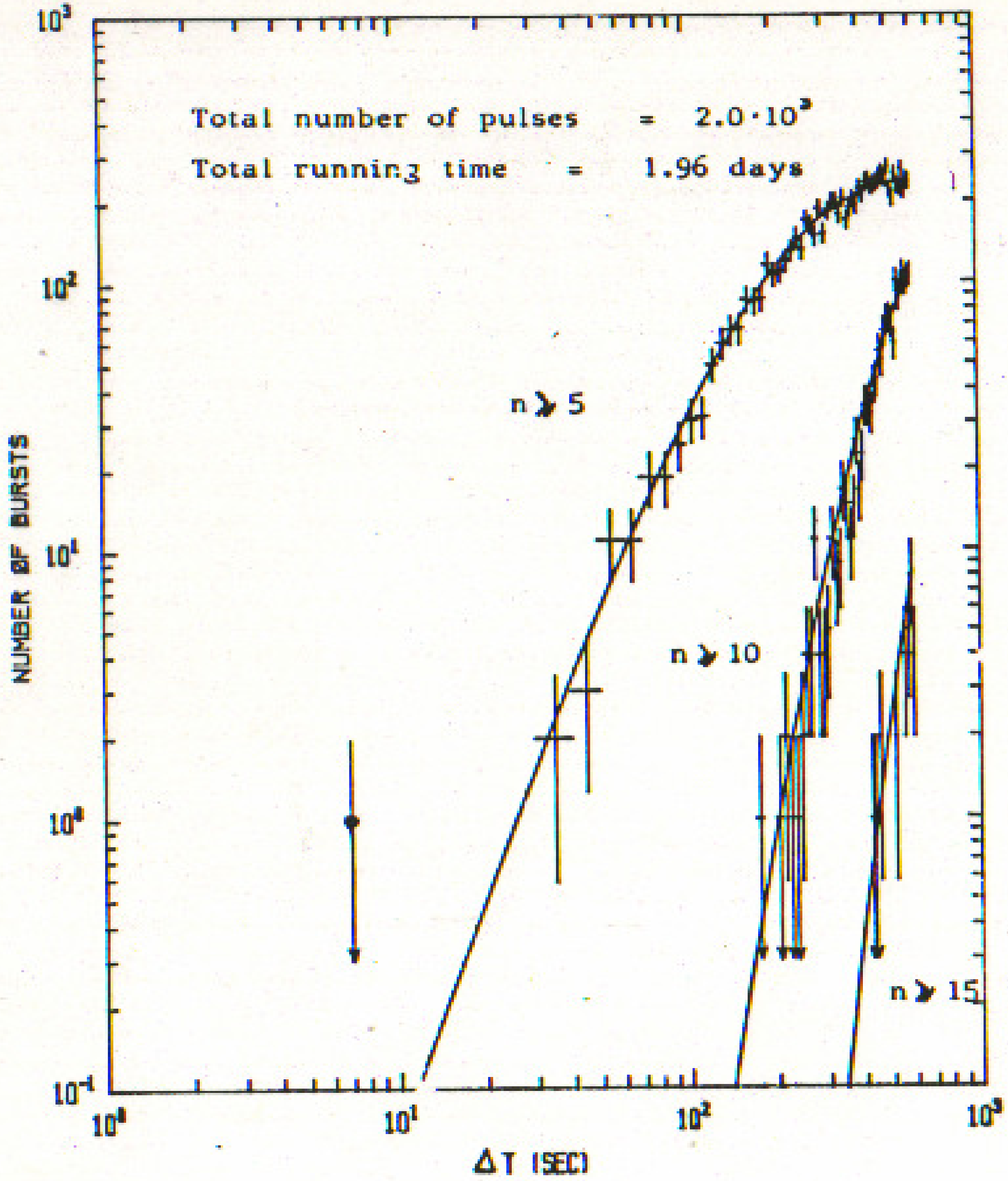
2 h 52 min.

On line print of five pulses on 23 February 1987 at 3 hr, 52 min, IT Detected at Mt. Blanc LSD experiment

```
          23 59 52.80/7 22 02 1987/CN 051 A 158/ SCR-0000240 REL 0128
*** PDP-11 DATE/TIME WAS : 87/02/23    00:00:07:24
*** INEGF CLOCK DATE/TIME IS   :        23    00:00:00:29 ( 591 MSEC  *** SOLAR TI
CLOCK    --   STOP

LSDMON   --  23-FEB-87 00:12:59 *** HIST.UPDATE AT EVENT 761 RUN 1328

LSDM02   --  23-FEB-87 01:28:10 *** UPDATE HIST. FILE 2 ***

LSDMON   --  23-FEB-87 01:33:52 *** HIST.UPDATE AT EVENT 861 RUN 1328

LSDMON   --  23-FEB-87 02:12:48 *** EMPTY/ERRORED EVENT 900 RUN 1328

LSDMON   --  23-FEB-87 03:17:08 *** HIST.UPDATE AT EVENT 962 RUN 1328

LSDM02   --  23-FEB-87 03:37:47 *** UPDATE HIST. FILE 2 ***

LSDM02   --  23-FEB-87 03:52:47 !!!!!!!! BURST OF   4 EVENTS  !!!!!!!!

 3:52:42.696 23- 2-87    TIME =      5.904 SEC.  EV.ATTESI =   0.07    FREQ.IMIT =   0.523E-01 /DAY
EV   994  TANK 31   ADC   33 L.E.P.   0
EV   995  TANK 14   ADC   37 L.E.P.   0
EV   996  TANK 25   ADC   46 L.E.P.   1
EV   997  TANK 35   ADC   32 L.E.P.   0
LSDM02   --  23-FEB-87 03:52:56 !!!!!!!! BURST OF   4 EVENTS  !!!!!!!!

 3:52:43.800 23- 2-87    TIME =      3.151 SEC.  EV.ATTESI =   0.04    FREQ.IMIT =   0.811E-02 /DAY
EV   995  TANK 14   ADC   37 L.E.P.   0
EV   996  TANK 25   ADC   46 L.E.P.   1
EV   997  TANK 35   ADC   32 L.E.P.   0
EV   998  TANK 33   ADC   40 L.E.P.   0
LSDM02   --  23-FEB-87 03:53:04 !!!!!!!! BURST OF   5 EVENTS  !!!!!!!!

 3:52:43.800 23- 2-87    TIME =      7.008 SEC.  EV.ATTESI =   0.08    FREQ.IMIT =   0.178E-02 /DAY
EV   994  TANK 31   ADC   33 L.E.P.   0
EV   995  TANK 14   ADC   37 L.E.P.   0
EV   996  TANK 25   ADC   46 L.E.P.   1
EV   997  TANK 35   ADC   32 L.E.P.   0
EV   998  TANK 33   ADC   40 L.E.P.   0
CLOSTR --
          04 52 52.90/1 23 02 1987/CN 052 A 158/ SCR 0000100 REL 0000
LSDMON   --  23-FEB-87 04:53:22 *** HIST.UPDATE AT EVENT 1062 RUN 1328
LSDM02   --  23-FEB-87 05:28:53 *** UPDATE HIST. FILE 2 ***
```

Number of bursts as function of their duration ΔT (sec) for Multiplicities n ≥ 5, ≥ 10 and ≥ 15

f=0.012 events/sec



Telex from
S. Cristiani from
ESO, Chile

27/02/1987

prot. 84/28.2.87

27/02 23.27 ⌀
224379 COSMOT I
~~27.02.87~~
TLX NO 612

ATT. O. SAAVEDRA

FROM.: S. CRISTIANI

SORRY FOR THE DELAY.
MORE DETAILED INFORMATION ABOUT THE SN 1987 A

1) THE DISCOVERY WAS MADE ON FEB 24.23, BUT, FROM PREVIOUS PLATES, IT HAS STARTED RISING BETWEEN FEB 22 AND FEB 23.443.

2) TYPE OF THE SN IS ALMOST CERTAINLY II AND THE PROGENITOR COULD BE A MASSIVE STAR, SANDULEAK -69. 202, OF ABOUT 12.2 V MAGNITUDE.

3) LUMINOSITY STILL TO BE COMPUTED IN DETAIL. AT PRESENT DATA ABOUT BOLOMETRIC LUMINOSITY ARE NOT AVAILABLE. AT PRESENT THE SN IS ABOUT 4.2 MAGNITUDE V.

4) APPROXIMATE DISTANCE = 52 KPC

MORE RELEVANT INFORMATION IN THE NEXT DAYS. PLEASE KEEP ME INFORMED ABOUT YOUR OBSERVATIONS.
CORDIALMENTE,

STEFANO
240881 ESOGO CL⌀
224379 COSMOT IMMMM

Circular No. 4332
I. A. U.

2/28/1987

0025+
0257103206842
NA
0025+
0257103206842+
~~28/02 14.37~~
ASTROGRAM CAM

224379 COSMOT I

TO DIRECTOR

IN THE MONT BLANC NEUTRINO OBSERVATORY ~~A SIGNAL HAS BEEN DETECTED~~ ON FEB.23RD AT 2:58 UT. THE NEUTRINO TELESCOPE, RUNNING SINCE OCT. 1984, AT 5000 M.W.E. UNDERGROUND, IN COLLABORATION BETWEEN OUR ISTITUTO DI COSMOGEOFISICA CNR, TORINO (ITALY) AND ACADEMY OF SCIENCES OF USSR MOSCOW (ZATSEPIN GROUP), CONSISTS OF 90 TONS OF LIQUID SCINTILLATOR IN 72 COUNTERS SHIELDED WITH 200 TONS OF FE SLABS.
THE RECORDED SIGNAL IS MADE BY 5 PULSES, ABOVE THE 7 MEV ENERGY THRESHOLD, DURING 7 SEC. THIS IS IN AGREEMENT WITH THE PREDICTIONS OF COLLAPSING FE-CORES STANDARD MODELS AT 50 KPC FARAWAY, BOTH IN ENERGY AND IN TIME DURATION.
THE PROBABILITY OF A RANDOM COINCIDENCE WITH SUPERNOVA SN 1987 A IS 1 ABOUT EVERY 10000 YEARS.
DETAILS WILL BE SEND SOON BY TELEFAX (PLEASE, LET US KNOW YOUR NUMBER).
BEST WISHES

CARLO CASTAGNOLI
DIRECTOR OF ISTITUTO COSMOGEOFISICA
TORINO - ITALY

ASTROGRAM CAM

224379 COSMOT IMMMMM

Events, detected by LSD

February,23, 1987 (SN 1987 A)

# of event	Time, UT±2ms	Energy, MeV
1	2:52:36,79	6,2 – 7
2	40,65	5,8 – 8
3	41,01	7,8 –11
4	42,70	7,0 – 7
5	43,80	6,8 – 9
1	7:36:00,54	8
2	7:36:18,88	9

Phase B

IMB, K-II and BST SN-neutrino detection time

Mainichi Daily News
65th Anniversary Year
Dedicated To International Understanding
No. 23012 (B) 日 刊 (大正11年4月10日第3種郵便物認可)
Tuesday, March 10, 1987
(昭和60年8月27日国鉄首都特別扱承認新聞紙第979号)

US-Japan Team Claims 1st Detection Of Neutrinos

A U.S.-Japan research team said Monday it has succeeded for the first time in the world in detecting elementary particles, called neutrinos, emitted by an exploding star.

The Japanese scientists cast doubt on a similar announcement last Thursday by a team of Italian and Soviet scientists in Europe.

They said their observation, on Feb. 23, was the first detection of neutrinos emitted from outside the solar system.

The European scientists claimed to have made the observation five hours earlier on the same date.

The observation concerns neutrinos from a supernova in the large Magellanic cloud, a satellite galaxy that lies beyond the fringes of the Milky Way, about 150,000 light years from the earth.

But the Japanese scientists doubt the accuracy of the observation made by the European group, because they said the device they used is more sophisticated than the Italian detector built beneath the Alps.

The Japanese device is 1,000 meters below the ground at an observatory belonging to Tokyo University in Kamioka, Gifu Prefecture.

The U.S.-Japan joint research group, led by Masatoshi Koshiba, a professor in the science department at Tokyo University, said it detected 11 neutrinos within 13 minutes from 7:35.35 (GMT) on Feb. 23 using the device.

The scientists belive the first two of the 11 neutrinos were from the supernova, because they both came from the direction of the large Magellanic cloud, Prof. Koshiba said.

During the first two seconds, 7.5 million to 36 million electronic volts of electron energy was observed, he said.

Of the 11 neutrinos, nine were believed to have been antineutrinos, he said.

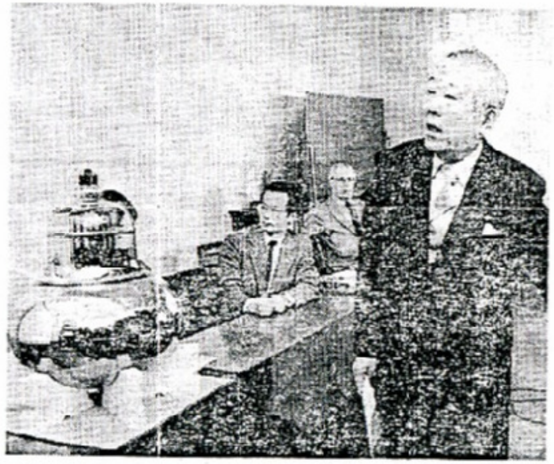
The scientists estimate that 10 billion neutrinos have reached the earth per square centimeter from the supernova and the temperature of the supernova is 30 billion degrees centigrade.

The Japanese device, cylindrical in shape, is 15.6 meters in diameter and 16 meters high. It is filled with 3,000 tons of pure water and equipped with 1,000 photo electron multipliers.

Neutrons emit blue light when neutrinos collide with electrons in water. Neutrinos are minute particles emitted when neutrons disintegrate into protons and electrons.

The discovery confirms a theory that when massive stars exhaust their nuclear fuel at the final stage of their evolution, exploding as supernovas, they emit large quantities of neutrinos, scientists said. The sun also emits neutrinos.

Neutrinos, whose mass is near zero, can penetrate any body and contain much information about stars. They are believed to hold a key to solving the mysteries of the creation of the universe.



Tokyo University Professor Masatoshi Koshiba announces the detection of neutrinos from a supernova in the Magellanic cloud.

Reagan Received 2 Reports On Irangate

WASHINGTON (AFP-Jiji) — President Ronald Reagan last year was twice told by his national security adviser at the time, Vice Admiral John Poindexter, that the profits of arms sales to Iran were diverted to Nicaragua's Contra rebels, The Washington Post reported Sunday.

The paper, quoting what it ...

investigating the affair is soon to make a decision on whether to offer Poindexter immunity from prosecution in return for his testimony.

So far he has pleaded the Fifth Amendment of the Constitution, which allows him to refuse to testify for fear of incriminating himself.

Nunn Wants Soviet Troop Reductions

WASHINGTON (AP) — Senator Sam Nunn called Sunday for a link between the removal of all U.S. intermediate-range missiles from Europe and a Soviet reduction in Moscow's conventional forces there.

Nunn is chairman of the Senate Armed Services Committee and one of the most respected voices in Congress on military strategy.

His remarks come at a time when the United States and ...

equal number on its territory.

Nunn, interviewed on the U.S. ABC television network, said that such a treaty should be connected to Soviet reductions in its troop strength in Europe.

"We ought to serve notice in advance to the Soviet Union ... that one of the things we would look at before we withdrew all those missiles — let's say the last 20, 25 percent — we will look at the conventional balance and the ...

82 Bodies Believed Trapped In British F...

ZEEBRUGGE, Belgium (AP) — Salvage experts were to continue their work Monday to raise the half-submerged ferry lying on its side in the North Sea, with the bodies of 82 people believed trapped inside.

With 53 bodies already recovered, the death toll is likely to be 135, making it the worst accident in modern times involving an English Channel ferry.

The Dutch company Smit Tak of Rotterdam sent two salvage ships with giant cranes Sunday, and crews worked until sundown in near-freezing temperatures to attach steel cables to the orange-and-white hull.

Workers may spend weeks welding steel loops to the hull in various places, attaching cables to the loops, and hoisting the vessel upright.

When the Herald of Free Enterprise is upright, they hope to recover the remaining bodies. The 82 missing people were presumed dead, trapped in the vessel.

Relatives, meanwhile, were filing past rows of coffins in a makeshift morgue in a basketball court to identify the victims. Officials said Sunday evening that 22 of the 53 bodies recovered so far had been identified by family members. No names or nationalities were disclosed.

With the last flickering hopes of finding more survivors aboard the vessel extinguished, the death toll was likely to be 135, assuming the count of 543 passengers and crew aboard is correct. Officials say there were ...

tional shock" and "blaming himself" for the accident, but gave no details.

He was responding to a Sunday report in a London newspaper saying Stanley, 28, blamed himself for the disaster because he left a loading door open that allowed the torrent of water into the ferry.

The British news agency Press Association quoted unidentified divers as saying the propellers of the ferry were set full astern — apparently a sign that Capt. David Lewry was trying to stop the ship.

A retired skipper of a similar Townsend Thoresen ferry, Capt. Oliver Elson, was quoted by the agency as saying the position of the propellers would indicate Lewry was employing a maneuver known as a "crash stop."

Lewry, 46, was in intensive care with a punctured lung, his lawyer, Graham Bridge told reporters. Bridge said the captain, who fell the width of the ship when it keeled over, was inter-

viewed brie... at his hospi...

Meanwh... drivers wh... Herald of F... sized Frida... sailed 10 to... cause the cr... ble closing...

Driver ... said: "T... close them ... The boat sa... as soon as s... was flooding... this disaster... she took in ...

"As the c... hand turn to... outside the h... shifted to on... boat over. T... bang. We di...

Fellow su... bons, 39, ad... three emerg... ship's carpe... sudden, the ...

The vessel ... minutes.

Raimond Call... Mart-Opening

French Foreign Minister Jean-Bernard Raimond called on Japan Monday to further open its market to the European Community to help correct a trade imbalance.

Raimond, who arrived here Saturday, made the request in a meeting with Shintaro Abe, chairman of the Executive Coun-

diversion of ... from the U.S...

He also as... French comp... U.S. firms in... New Kansai... port project.

Raimond s... surplus with ... creasing yea...

$\Delta t = \pm 50\ ms$

Table I: Summary of IMB Events

Event Time	Relative Time	Cosine from SN	Angle from SN	Energy (MeV)
7:35:41.374	0.000	0.172	80±10	38±7
7:35:41.786	0.412	0.720	44±15	37±7
7:35:42.024	0.650	0.563	56±20	28±6
7:35:42.515	1.141	0.414	65±20	39±7
7:35:42.936	1.562	0.843	33±15	36±9
7:35:44.058	2.684	0.610	52±10	36±6
7:35:46.384	5.010	0.738	42±20	19±5
7:35:46.956	5.582	-0.246	104±20	22±5

$\Delta t = \pm 60 sec$

Table II: Summary of Kamioka Events

Event Time	Relative Time	Cosine from SN	Angle from SN	Energy (MeV)
7:35:35	0.000	0.951	18.±18.	20.0±2.9
7:35:35	0.107	0.966	15.±27.	13.5±3.2
7:35:35	0.303	-.309	108.±32.	7.5±2.0
7:35:35	0.324	0.342	70.±30.	9.2±2.7
7:35:36	0.507	-.707	135.±23.	12.8±2.9
7:35:36	0.686	0.375	68.±77.	6.3±1.7
7:35:37	1.541	0.848	32.±16.	35.4±8.0
7:35:37	1.728	0.866	30.±18.	21.0±4.2
7:35:37	1.915	0.788	38.±22.	19.8±3.2
7:35:44	9.219	-.530	122.±30.	8.6±2.7
7:35:45	10.433	0.656	49.±26.	13.0±2.6
7:35:47	12.439	-.017	91.±39.	8.9±1.9

$\Delta t = +2$ sec
-54sec

Table III: Summary of Baksan Events

Event Time	Relative Time	Energy (MeV)	Internal or External
7:36:11.818	0.000	12±2.4	Internal
7:36:12.253	0.435	18±3.6	Internal
7:36:13.528	1.710	23.3±4.7	External
7:36:19.505	7.687	17±3.4	External
7:36:20.917	9.099	20.1±4.0	External

Mt. Blanc – LSD events

$$\Delta t = \pm 2ms$$

7 hr 36 min. 005s 9.0 MeV tank 2
7 hr 36 min. 18.9s 6.4 MeV tank 14
Europhys. Lett. **3**,*1315,1987*

OFF LINE

U.T.

EVENT	TIME	TANK	ADC	
980	2:37:43.5	11	35	
981	2:38:24.9	13	49	
982	2:39:22.7	50	36,14	
983	2:39:35.6	3	255	μ
		9	208	
		10	255	
		16	255	
		23	255	
984	2:42:03.2	TDC TEST		
985	2:42:11.1	69	37,13,13	
986	2:42:27.6	31	42	
987	2:43:47.4	35	33	
988	2:43:58.5	61	39	
989	2:44:29.2	41	45	
990	2:45:26.4	42	45,13	
991	2:45:38.8	59	50	
992	2:49:12.7	TDC TEST		
993	2:52:02.0	16	35	
994	2:52:36.8	31	33	burst
995	2:52:40.6	14	37	
996	2:52:41.0	25	46,14	
997	2:52:42.7	35	32	
998	2:52:43.8	33	40	
999	2:53:47.3	63	40,24	
1000	2:55:51.2	11	49	
1001	2:56:12.1	55	44,12	
1002	2:56:22.2	TDC TEST		
1003	2:56:24.6	5	255	μ
		11	59,13	
		29	113,14	
1004	2:58:14.8	31	43,17,15	
1005	2:59:28.3	42	44	
1006	2:59:46.6	43	39	
1007	2:59:50.6	11	255	μ
		35	255	
		59	255	
1008	3:00:01.5	25	44	
1009	3:01:04.7	61	44,17,16	
1010	3:01:39.6	1	38	
1011	3:01:47.2	3	34	

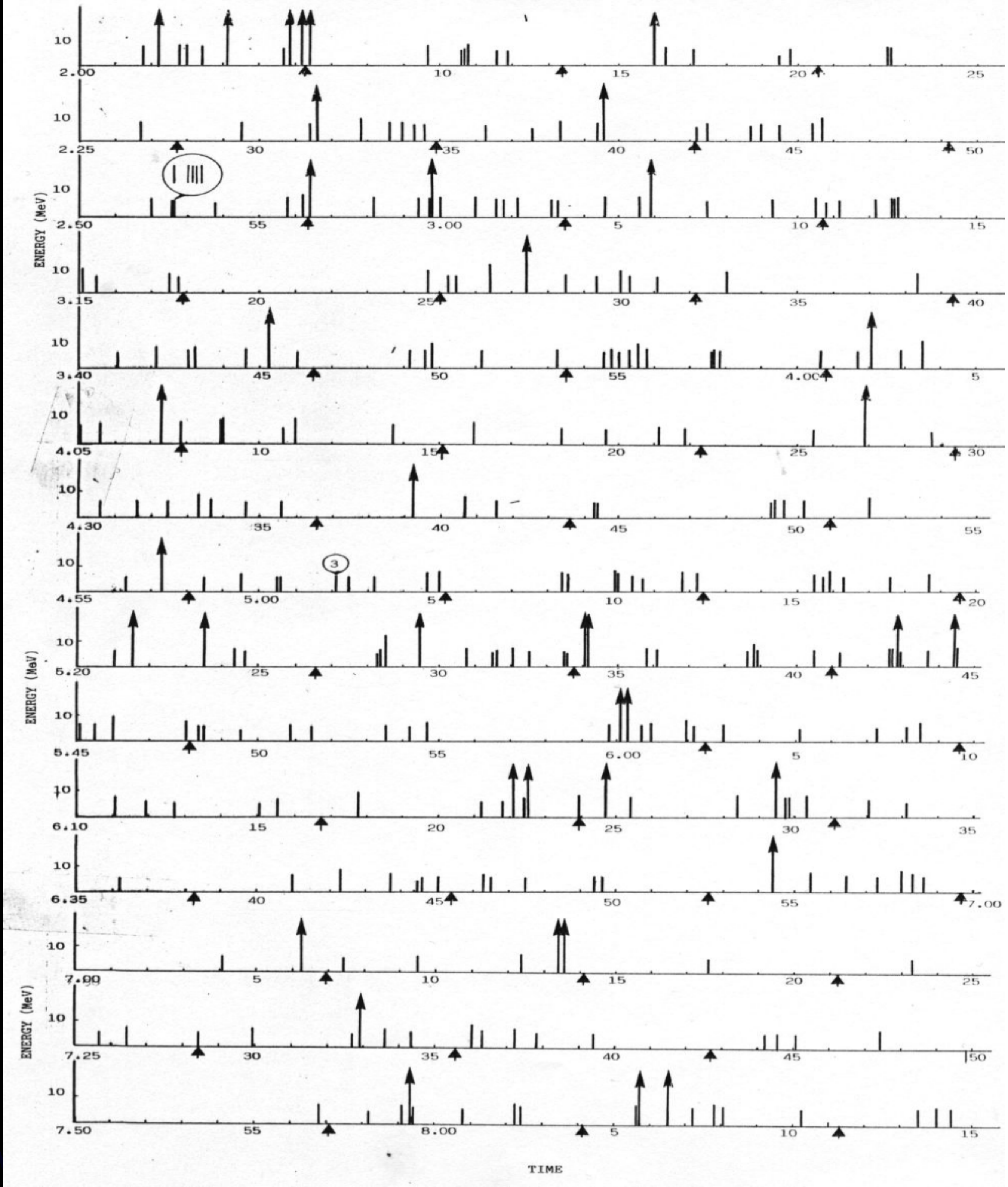
7.0 sec (events 994–998, burst)

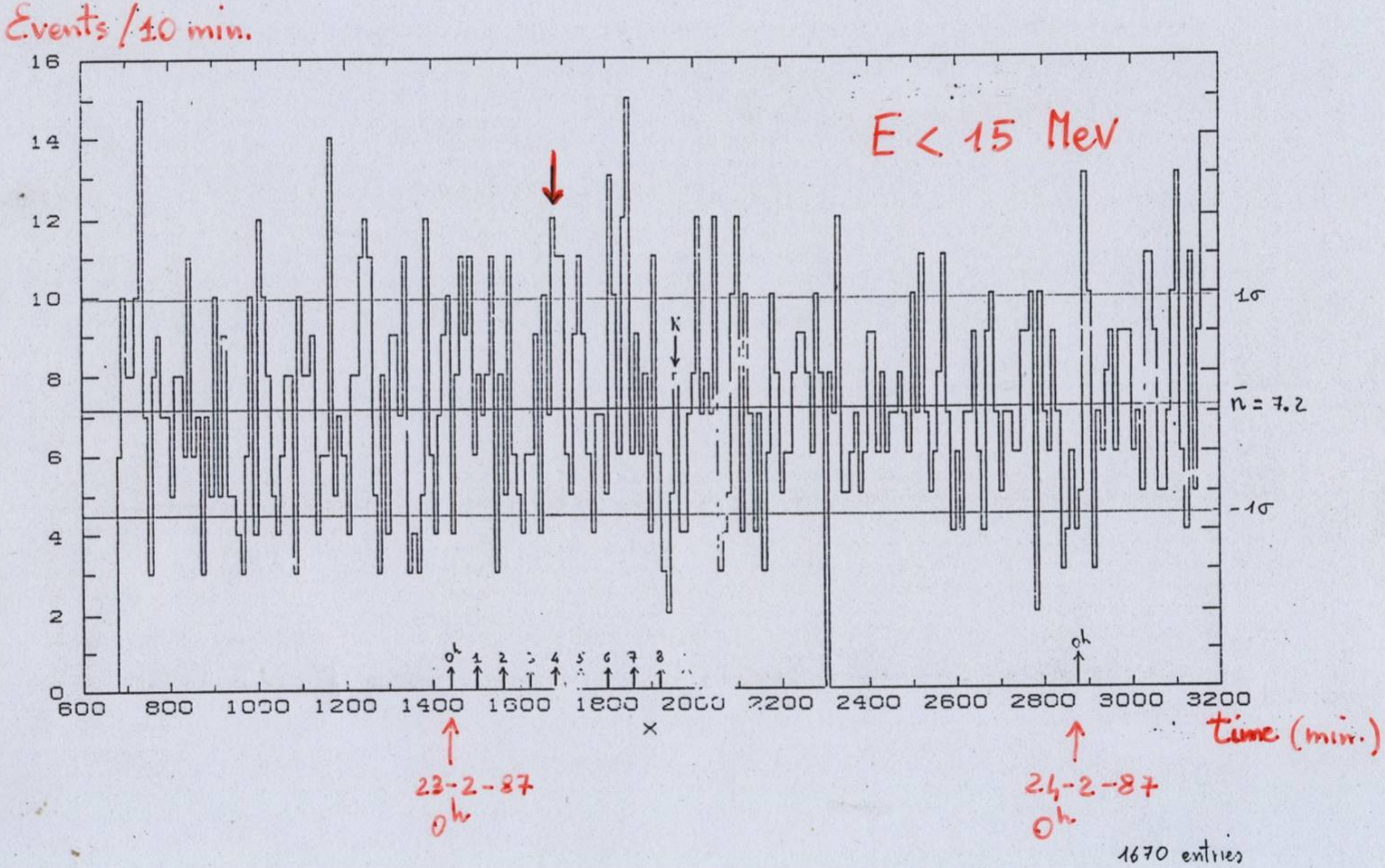
All pulses recorded in LSD from 2:37:43 to 3:01:47 UT on Feb.23
Events No. 983, 1003 and 1007 are cosmic ray muons

EVENT	TIME	TANK	ADC	
1270	7:13:35.2	10	255	μ
		11	184	
		28	106	
		29	255,41	
		53	255	
1271	7:14:04.1	TDC TEST		
1272	7:17:35.5	4	26,10	
1273	7:21:13.6	TDC TEST		
1274	7:23:19.0	14	34	
1275	7:25:46.4	1	42	
1276	7:26:28.1	12	48	
1277	7:28:23.1	TDC TEST		
1278	7:28:25.3	10	36	
1279	7:29:57.1	6	45,16	
1280	7:32:43.9	41	41	
1281	7:32:53.9	25	255	μ
1282	7:33:39.7	20	37	
1283	7:34:21.6	17	36	
1284	7:35:32.6	TDC TEST		
1285	7:36:00.5	2	34	
1286	7:36:18.9	14	38	
1287	7:37:12.8	20	42,11	
1288	7:37:50.1	31	35,15,14	
1289	7:39:25.2	27	35,14	
1290	7:42:42.1	TDC TEST		
1291	7:44:09.1	41	40	
1292	7:44:33.0	53	42	
1293	7:45:08.6	14	33	
1294	7:47:24.9	33	40	
1295	7:49:51.6	TDC TEST		
1296	7:56:47.4	35	42	
1297	7:57:01.1	TDC TEST		
1298	7:58:11.3	41	35	
1299	7:59:08.2	54	45,12,15	
1300	7:59:17.1	25	255,22	μ
1301	7:59:18.5	17	42	

All pulses recorded in LSD near the Kamiokande-IMB.
Events No. 1281 and 1300 are cosmic ray muons

Scater plot of <u>all events detected</u> on Feb/23/1987 since 2:00:00 to 8:15:00 UT.
The Y axis is the energy up to 20 MeV. Large vertical arrows show The arrival time of cosmic muons. The small arrows, below the time axes are the authomatic electronic test.

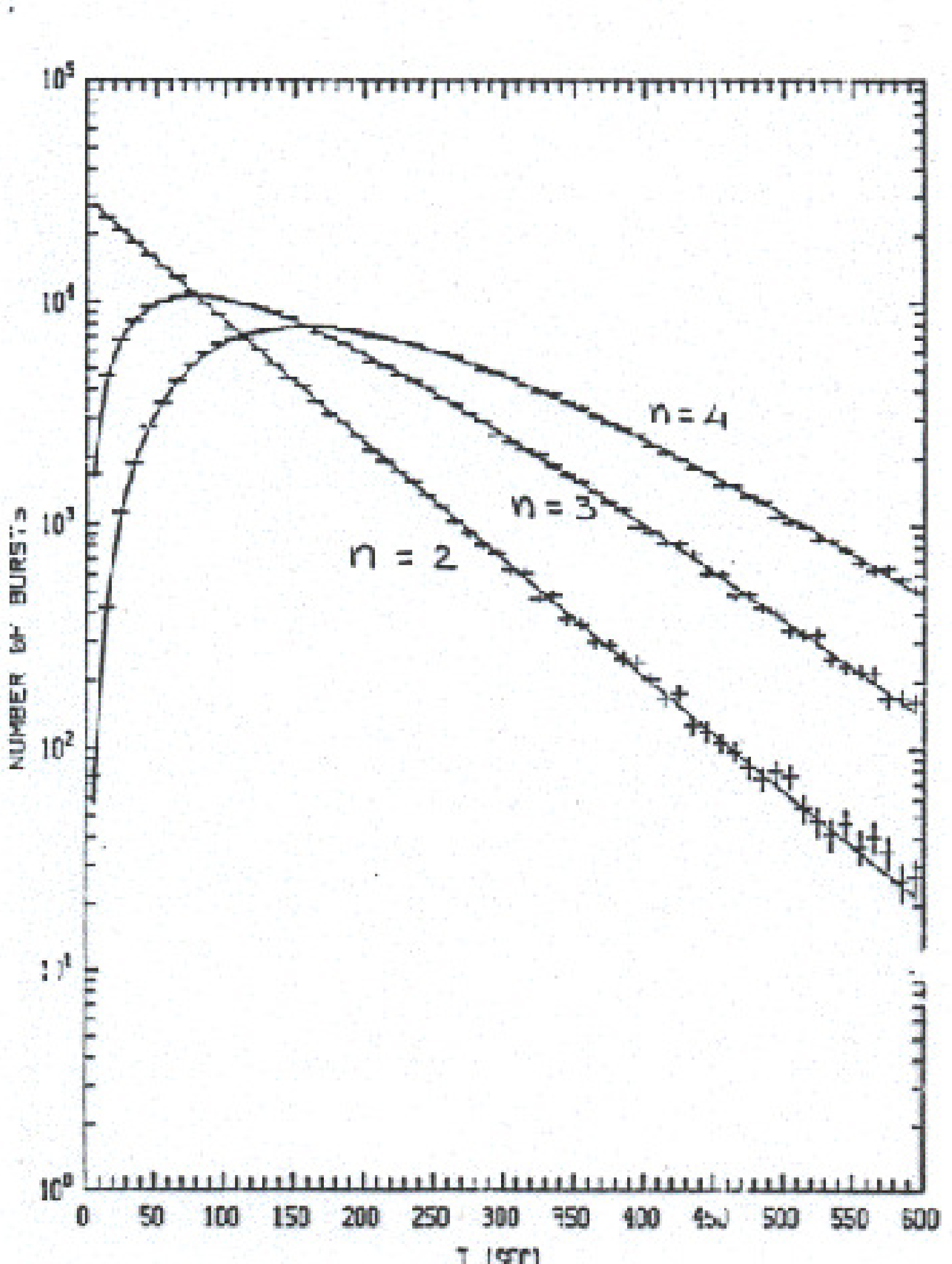


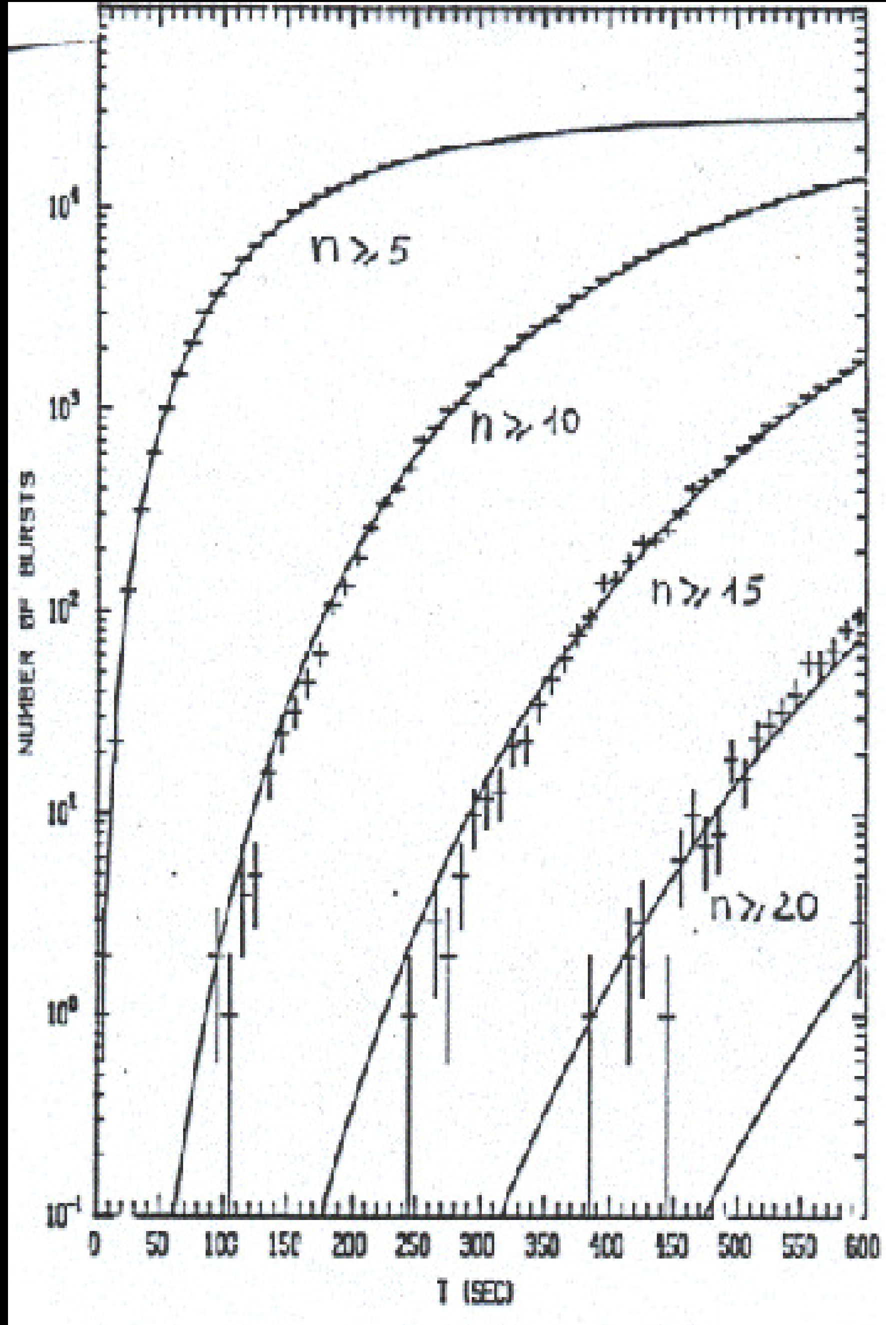


Events / 10 min.
E < 15 MeV
16
14
12
10
8
6
4
2
0
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
1σ
n̄ = 7.2
-1σ
K
0h 1 2 3 4 5 6 7 8
0h
time (min.)
23-2-87
0h
24-2-87
0h
1670 entries

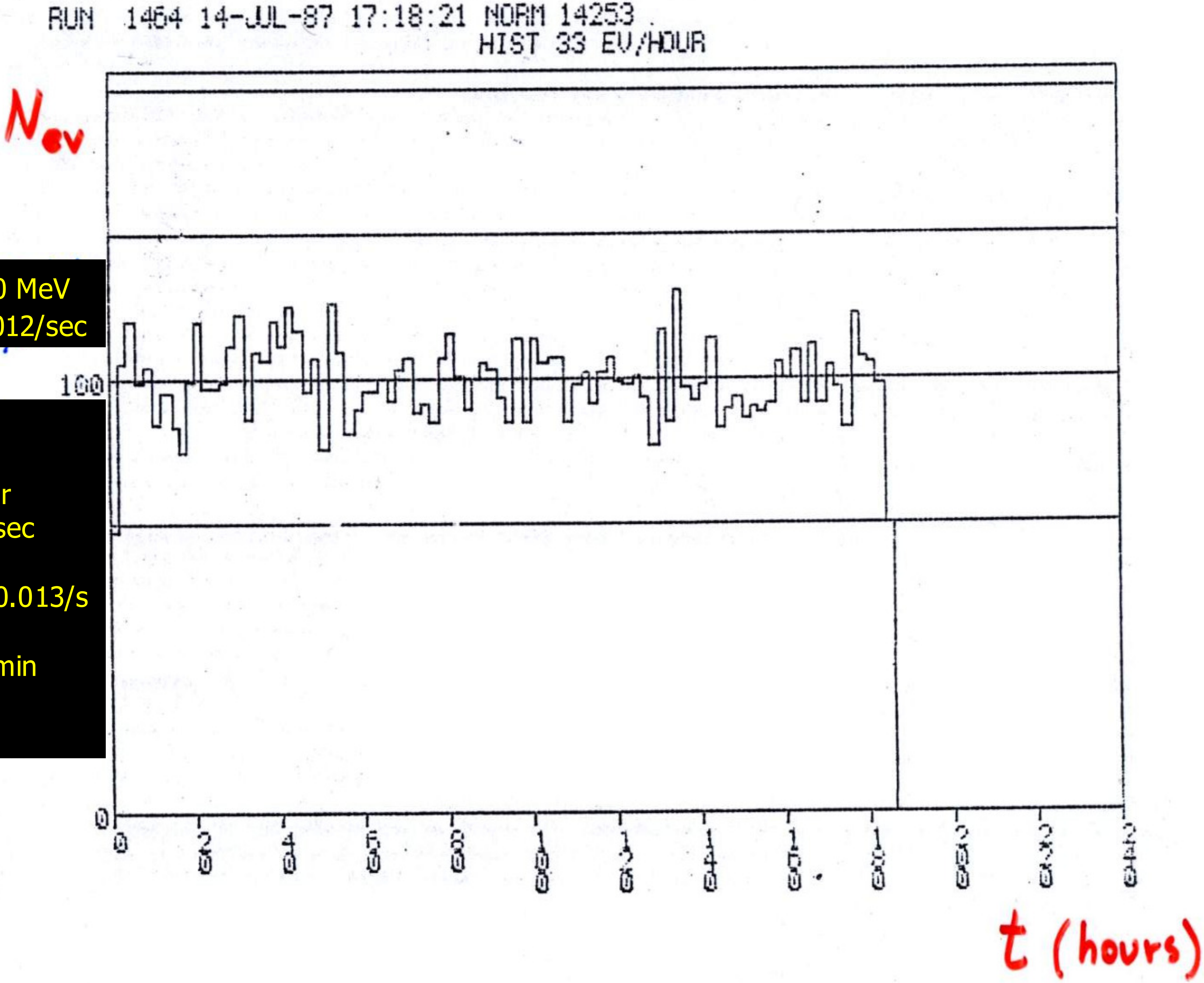
Number of burst as a function of thei duration for muliplicíyof pulses n=2, n=3 and n=4 (fig. a) and for n ≥ 5, n ≥ 10, n ≥ 15 and for n ≥ 20 (fig. b). From 9/28/1986 to 5/23/1987.

T=217.7 days, N = 234.168, <f>= 0.012 ev/sec





On line monitoring



for 7<E<60 MeV
freq. = 0.012/sec

Freq. of μ's
= 3.5/hr
= 10^{-3}/sec

total freq.=0.013/s

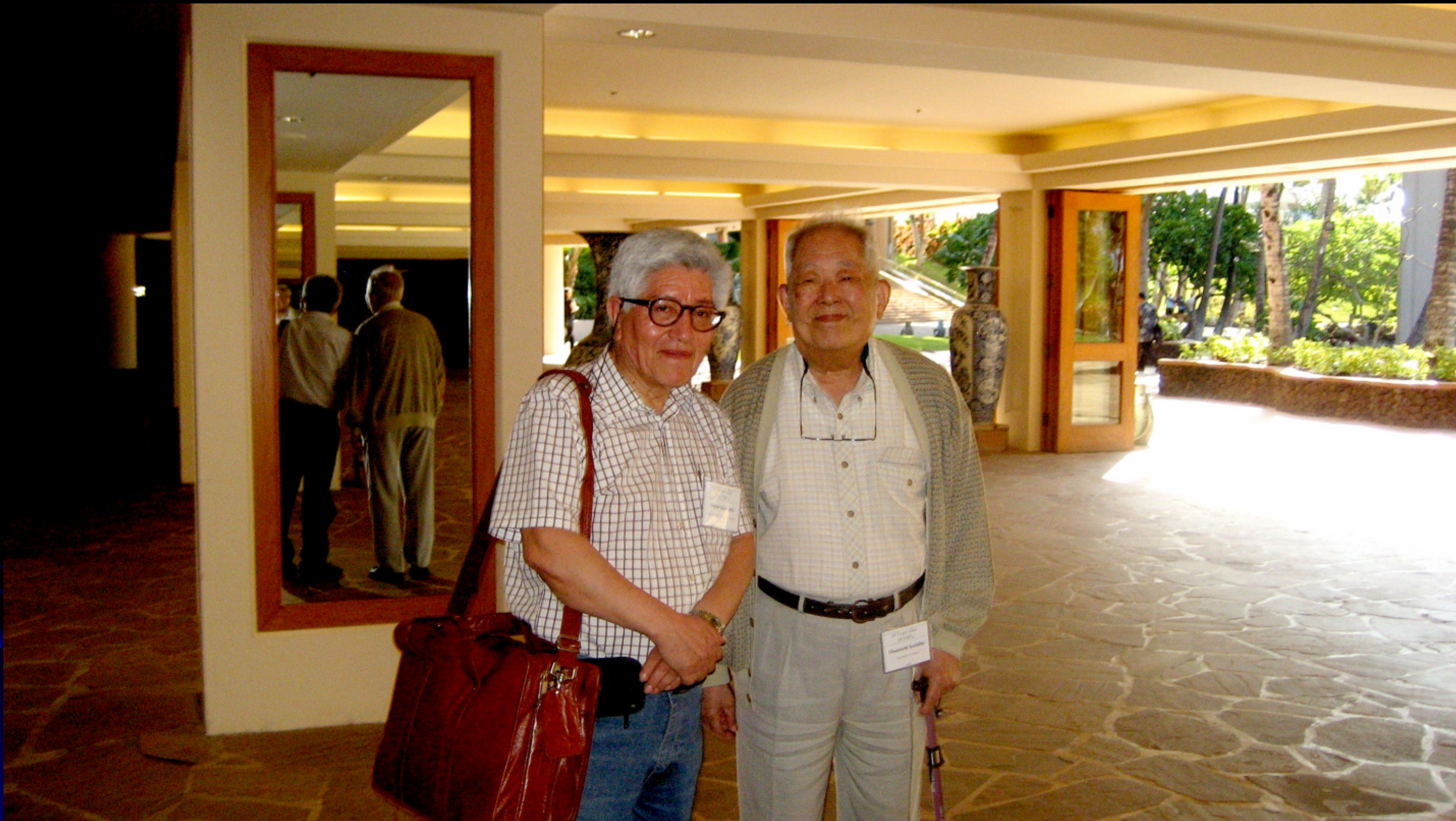
= 0.78/min

Two bangs can produced the two separated neutrino burst?

- De Rujula
- Imshennik and Ryazhskaya

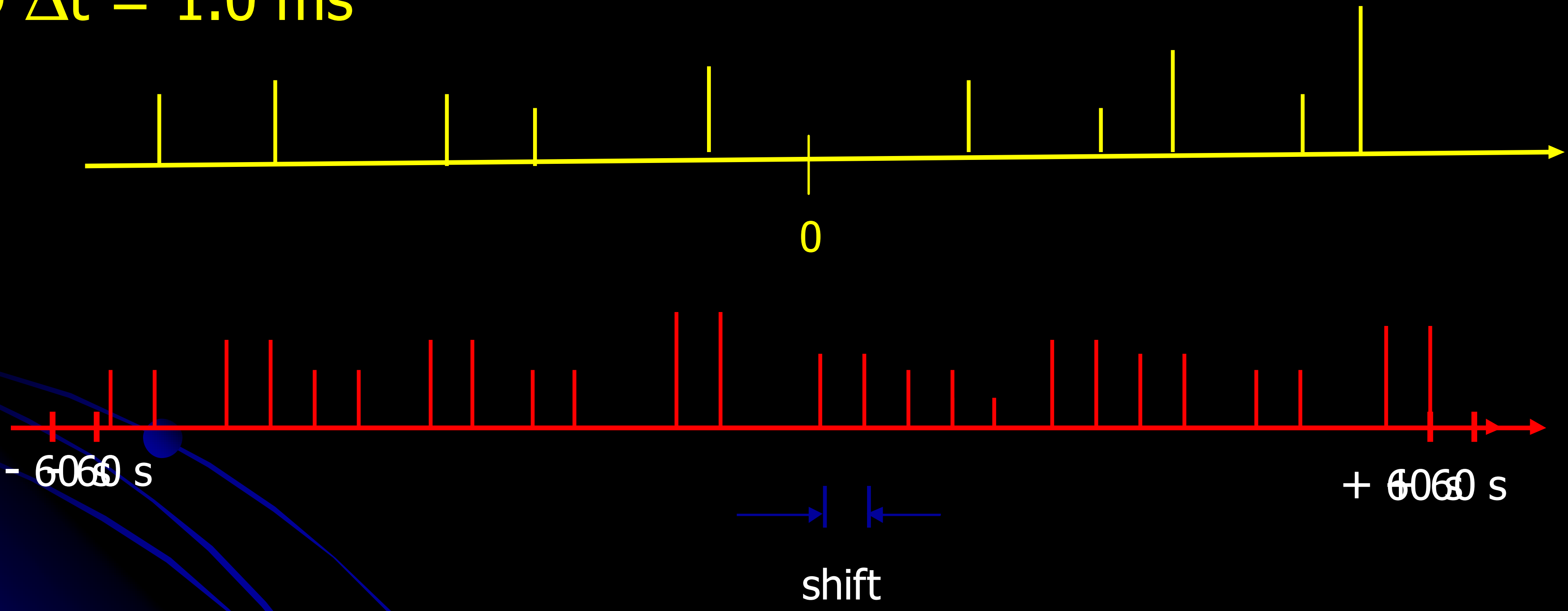
Phase C

Correllations between LSD - K-II and BST



Kamioka-LSD correlations

LSD Δt = 1.0 ms



Kamioka Δt= 60 sec

$$N_c = 2\frac{N_1 \cdot N_2}{T}\Delta\tau$$

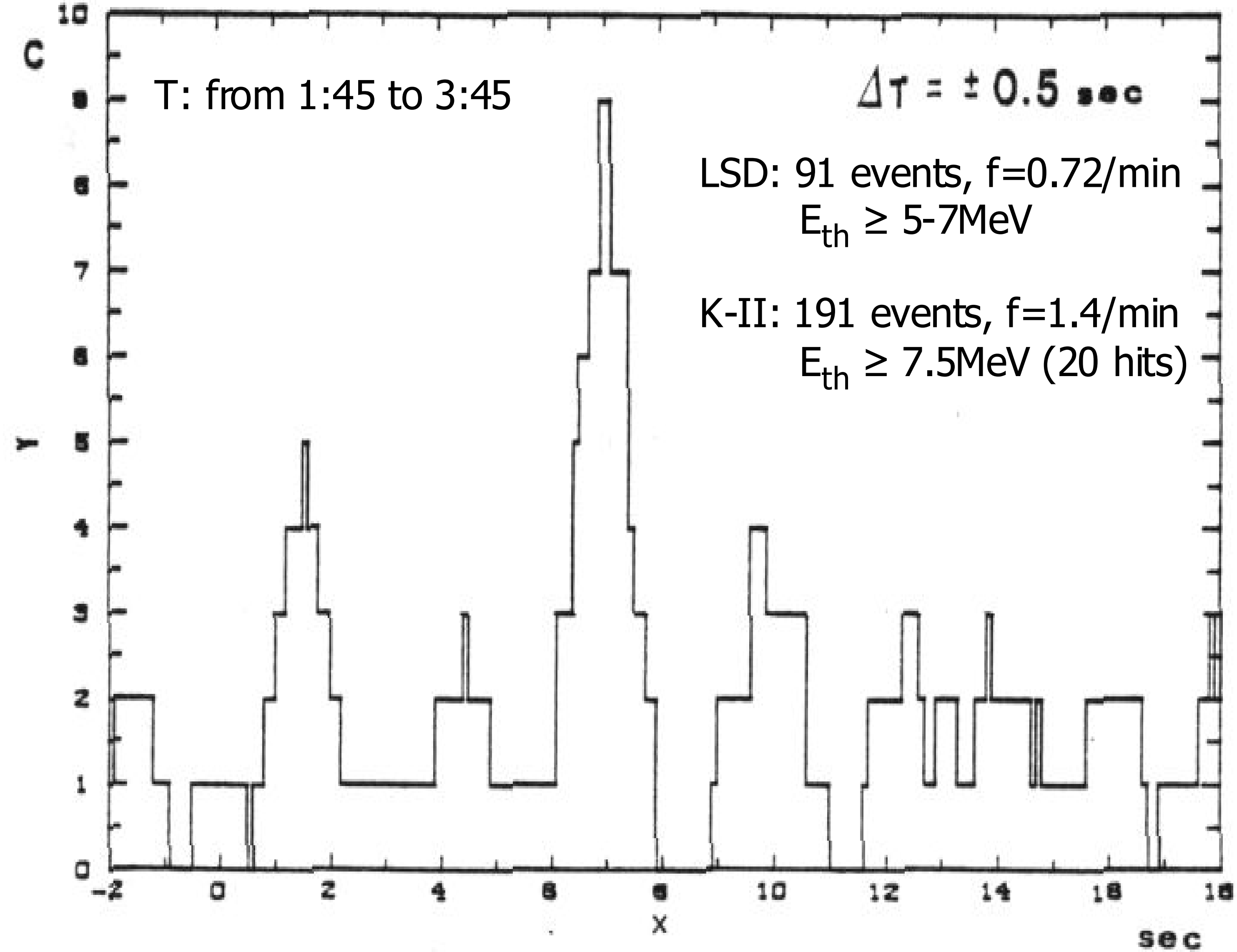
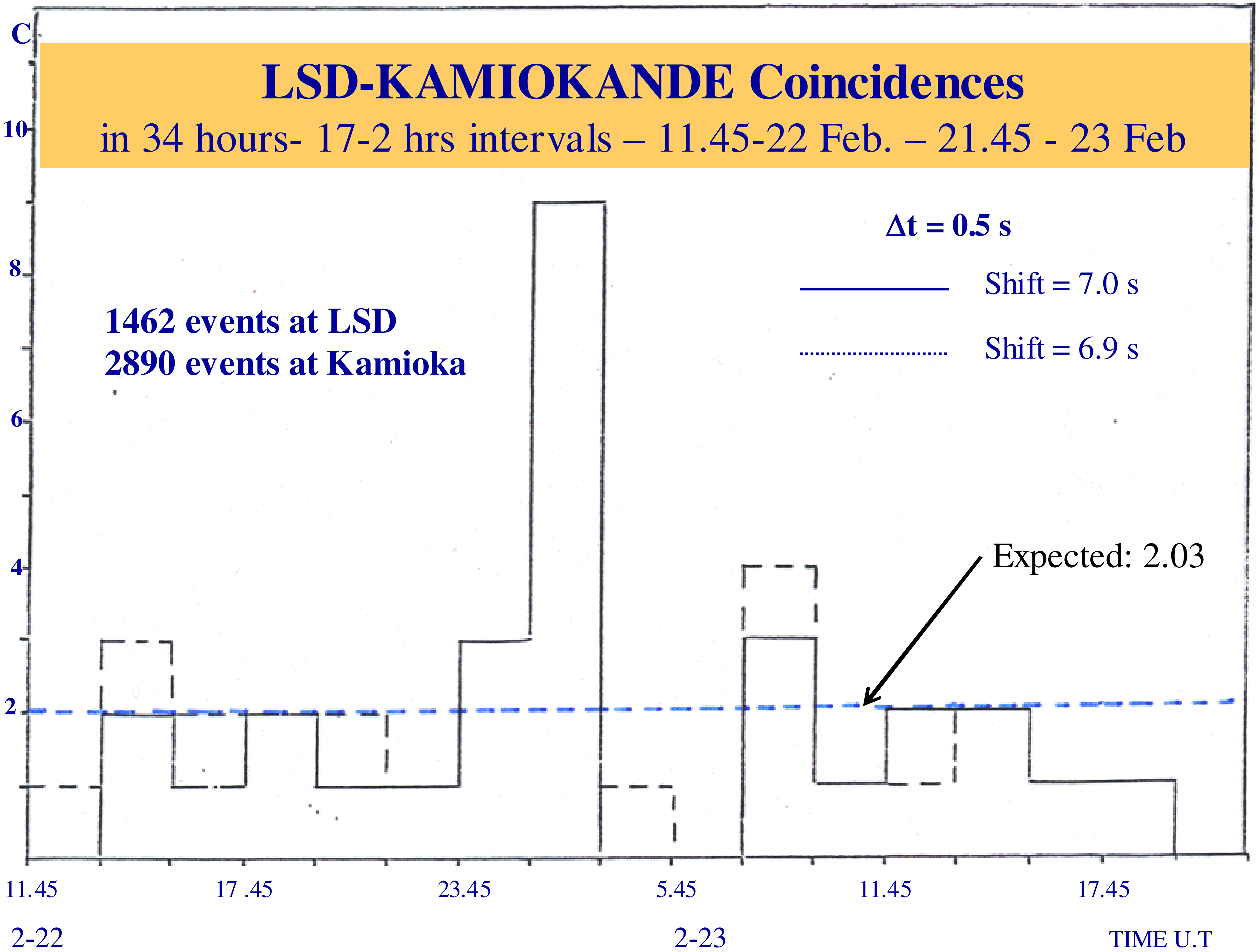


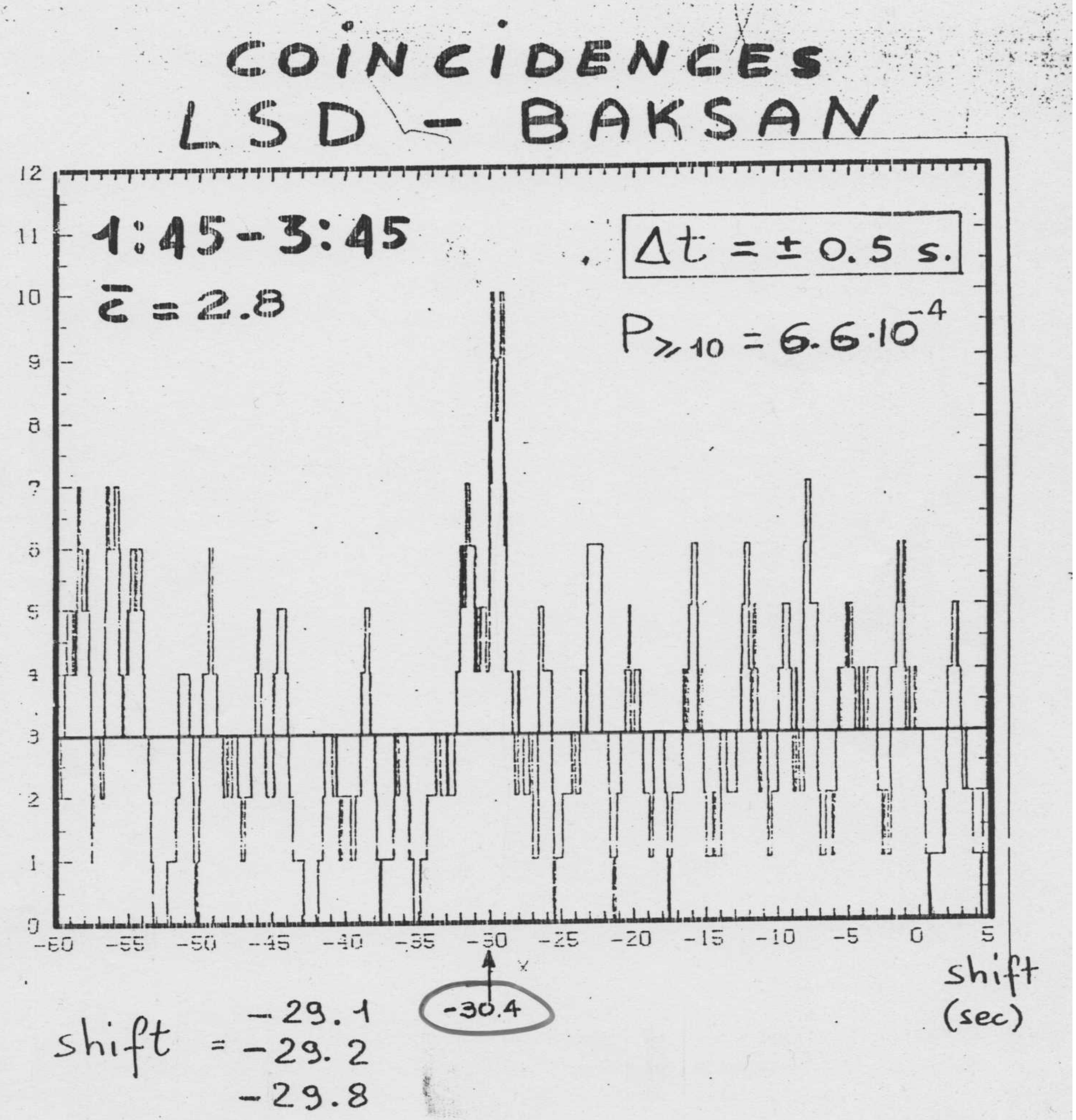
FIGURE 2. Distribution of the number of coincidences between K2 and LSD in the period from 1:45 to 3:45 U.T. on 23 February 1987 as a function of the time shift in the K2 absolute time.

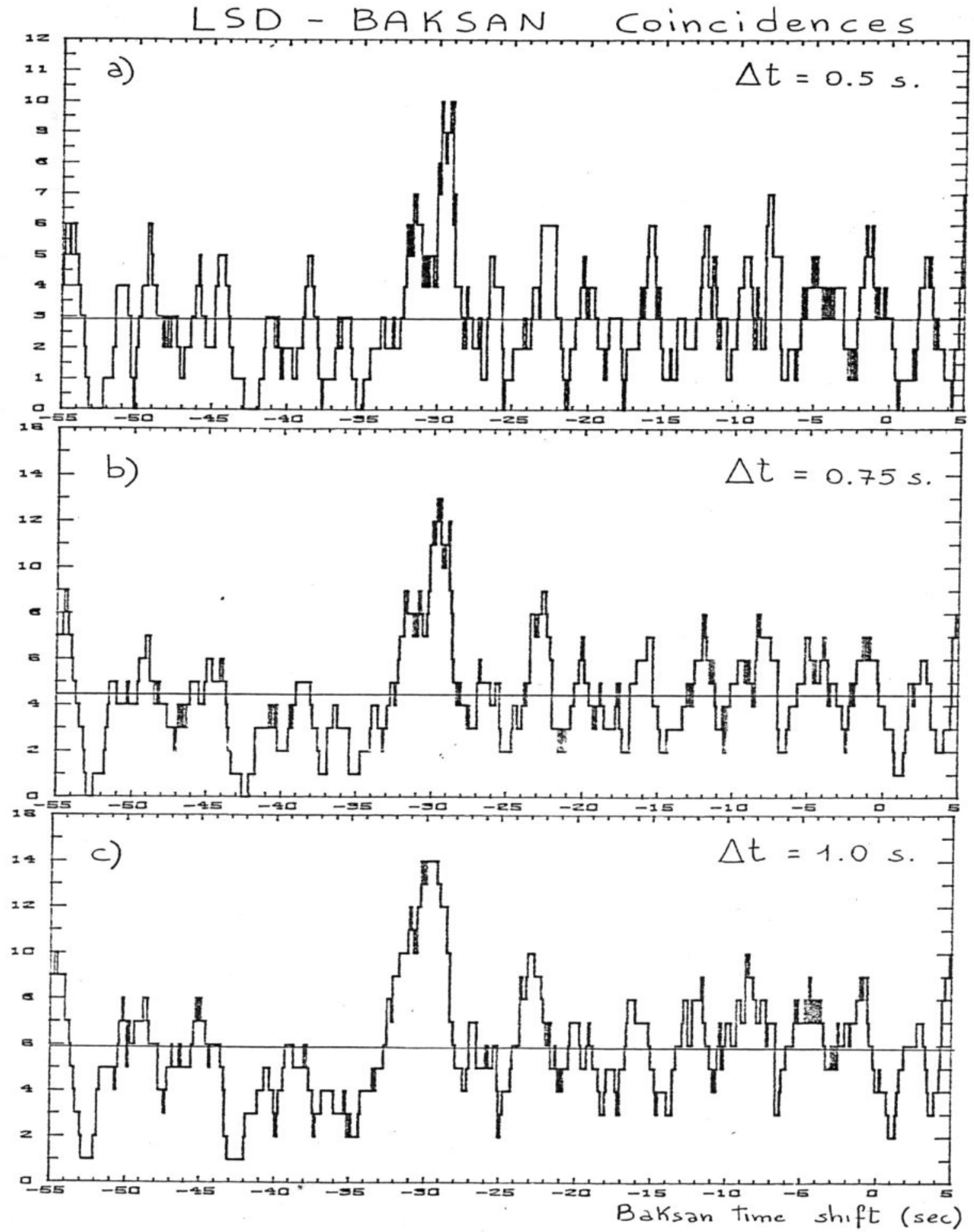
LSD-KAMIOKANDE Coincidences

in 34 hours- 17-2 hrs intervals – 11.45-22 Feb. – 21.45 - 23 Feb

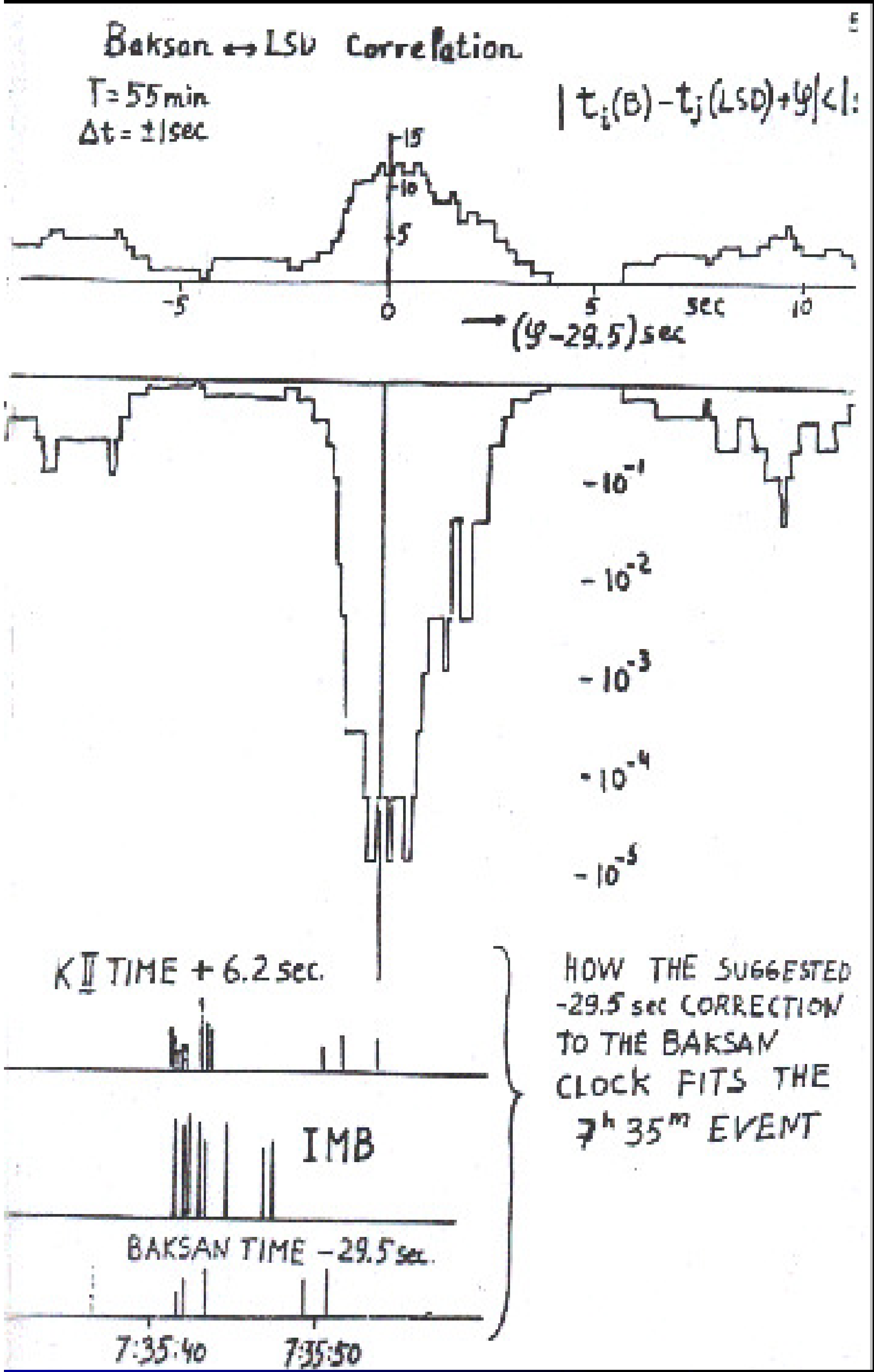


91 Mt. Blanc events
240 Baksan events

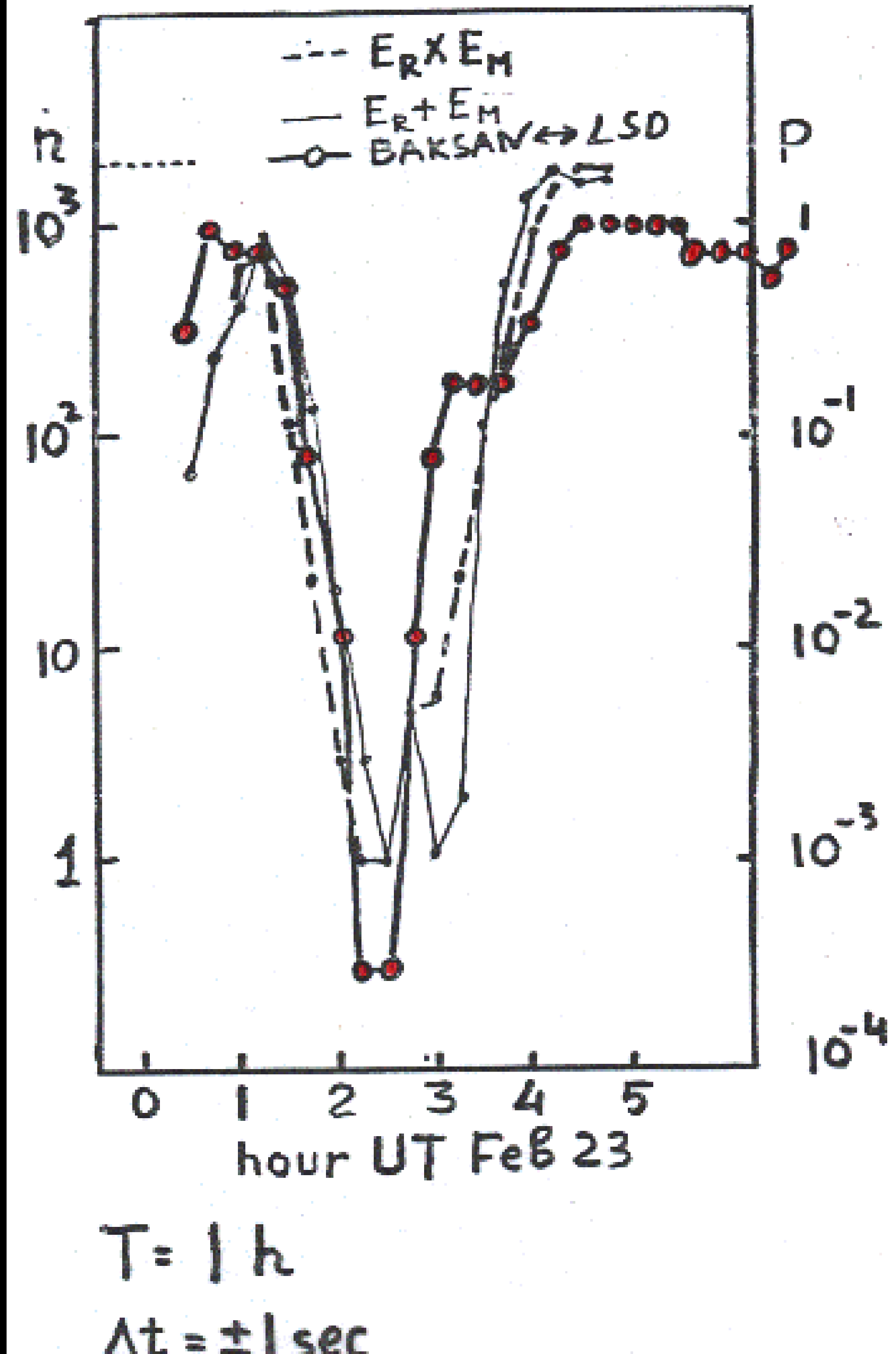




LSD - BAKSAN Coincidences
a)
Δt = 0.5 s.
b)
Δt = 0.75 s.
c)
Δt = 1.0 s.
Baksan time shift (sec)



Baksan ↔ LSD Correlation
T = 55 min
Δt = ±1 sec
|t_i(B) − t_j(LSD) + ψ| < 1 :
15
10
5
−5
0
5
sec
10
→ (ψ − 29.5) sec
−10^-1
−10^-2
−10^-3
−10^-4
−10^-5
K II TIME + 6.2 sec.
IMB
BAKSAN TIME −29.5 sec.
7:35:40
7:35:50
HOW THE SUGGESTED −29.5 sec CORRECTION TO THE BAKSAN CLOCK FITS THE 7h 35m EVENT



E_R × E_M
E_R + E_M
BAKSAN ↔ LSD
n
P
10^3
10^2
10
1
1
10^-1
10^-2
10^-3
10^-4
0
1
2
3
4
5
hour UT Feb 23
T = 1 h
Δt = ±1 sec

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On the Correlation between Mont Blanc and Baksan Underground Detectors in February 1987

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INTRODUCTION

After hearing the lecture of professor, E. Amaldi, at the Erice School (April 1988) concerning the observation of a correlation between gravitational antennas (G.A.) and Mont Blanc (LSD) signals[1] and then discussing the subject also with O. Saavedra in Torino, I suggested to look for a correlation directly between the LSD and Baksan data, thus of two quite similar underground scintillation detectors.

The idea is very simple: If something really happens that activates the G.A. signal and that, after 1.2 s, gives a signal in a particular scintillator, then there should be a chance to observe a quasi-simultaneous signal in another, possibly very distant scintillator. The big distance between the Baksan and LSD detectors should exclude the common electrical power supply as a possible source of correlation. Another advantage of the suggested search could be a simplicity of statistical analysis when the duration of the signal (in the scintillation counter) is much less than the correlation time interval (1 s).

Of course, the negative result of the proposed analysis would not mean a strict contradiction with reference 1 for at least two reasons:

(1) the probability of recording the signal in LSD is unknown;
(2) although the target mass of the liquid scintillator at Baksan is twice that of LSD, the energy threshold (10 MeV) is nearly two times higher than in LSD.

Both effects could make a cross-correlation of LSD-Baksan unobservable.

Certainly, I also did not expect a positive result because of the fantastic nature of the phenomenon in question. Therefore, most surprising was the news from O. Saavedra, who, after receiving the Baksan data, informed me of a positive effect in the LSD-Baksan correlation. Consequently, I made an independent analysis that unambiguously confirmed Saavedra's message. However, at the same time, we found some peculiar strangeness and possible internal contradictions in this correlation.

In this report, I would like to discuss both positive and "negative" evidence concerning the LSD-Baksan correlation. However, as the saying goes: the good news first, then the bad news.

POSITIVE EVIDENCE NO. 1

Following reference 1, we have to choose several quantities for our correlation analysis:

(1) Δt = the time gate or correlation time,
(2) T = the time period in which coincidences are summarized,
(3) t = the position of the center of the T period on the U.T. scale,
(4) t_0 = a relative shift of the time scales of the two detectors; in our case, a correlation of the Baksan clock.

We first choose $\Delta t = \pm 1$ s. One second is exactly the time gate chosen in reference 1 and the plus-minus sign arrives from the assumed symmetry of the detectors. The choice of Δt by intention is not made as an optimal one (for $\Delta t = \pm 0.2$ s or $\Delta t = \pm 2$ s, the result could be made more impressive).

Next, $T = 1$ hour is in our opinion a good choice, both improving the significance of the result by a factor of four (as compared with $T = 2$ hours) and indicating the maximum of activity better.

The choice of t = 2:15 U.T. is illustrated in FIGURE 1.

The choice of $t_0 = -29.5$ s for the correction of the Baksan clock is shown in FIGURE 2.

FIGURE 1 shows the significance of the correlation both for the G.A.-LSD pair

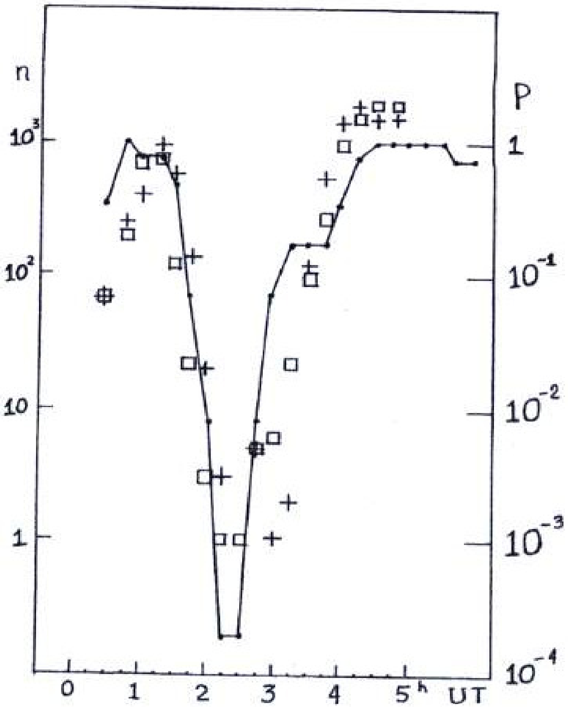


FIGURE 1. The significance of observed correlations for both G.A.-LSD (squares and crosses) and LSD-Baksan (dots and solid line) as a function of the position of the period T on the U.T. scale. Squares: $E_M \times E_R$ algorithm; crosses: $E_M + E_R$ algorithm (see reference 1).

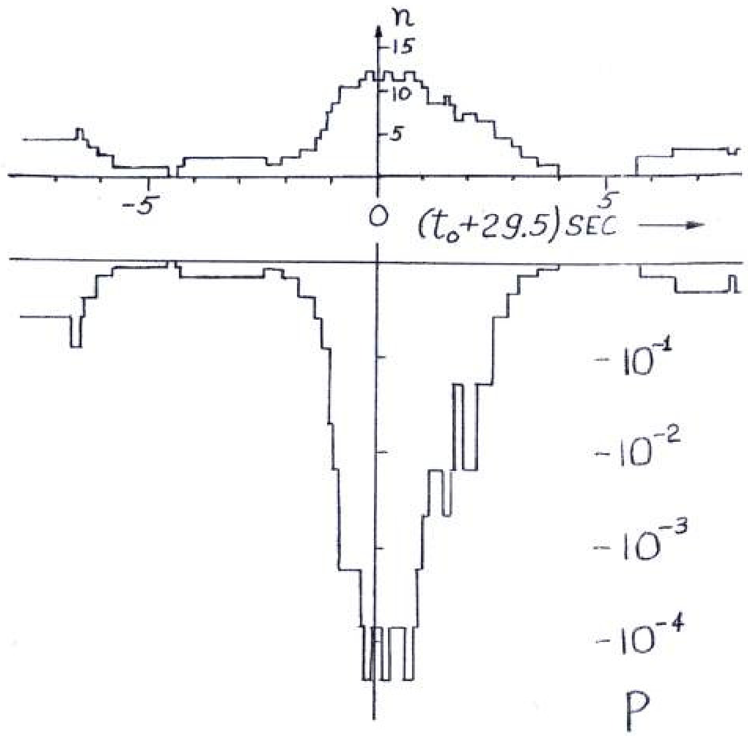


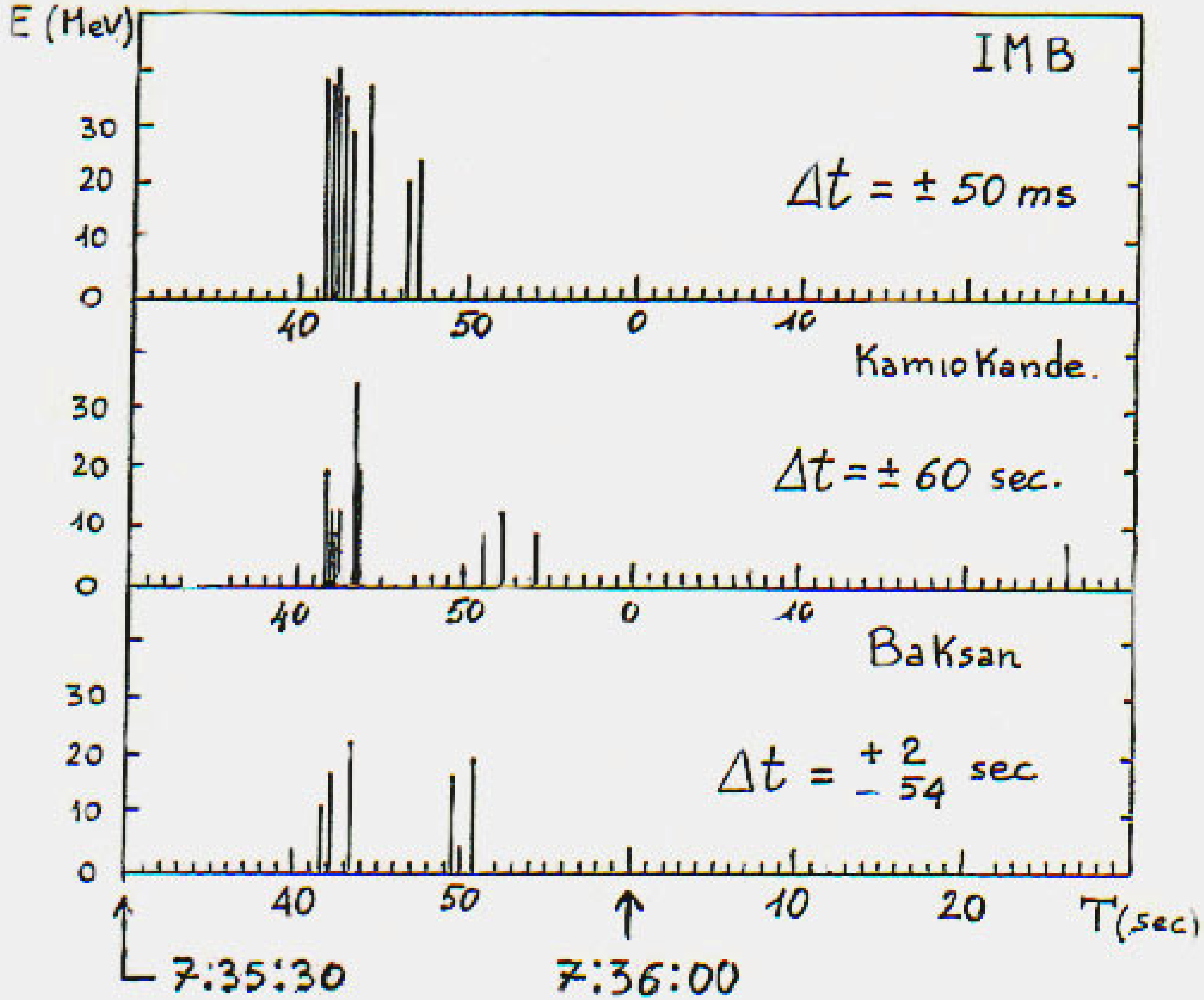
FIGURE 2. The number of LSD-Baksan coincidences as a function of the time shift, t_0 (top histogram). The Poisson probability to have the observed number or more (bottom histogram).

(crosses and squares) and the LSD-Baksan pair (solid line with dots). Note that data for the G.A.-LSD pair are taken from reference 1.

For both data, the time period of $t = 1$ hour is moved by steps of 15 min along the U.T. time scale. On the left vertical scale, the quantity, n, is plotted (see reference 1); $n = 2000$ roughly represents the chance probability to observe the recorded magnitude of the G.A.-LSD correlation. On the right vertical scale, the chance probability to observe the recorded number or a bigger number of LSD-Baksan coincidences, $\Delta t = \pm 1$ s, is plotted. Although this quantity strictly does not obey the Poisson distribution, the latter is quite a good approximation in our particular case. For t = 2:15, we have: N(LSD) = 44; M(Baksan) = 116; the mean (expected) value of coincidences is $\lambda = 2 \times 44 \times 116/3600 = 2.84$; the observed one is 11. The practical validity of the Poisson distribution of the number of coincidences for these particular figures was checked by 32,400 trials.

Looking at FIGURE 1, we see a striking similarity between the G.A.-LSD data and the LSD-Baksan data. The correlation arrives at the same time and, approximately, with the same strength. The probability of this to happen by chance is $P = 2 \times 10^{-4}$. However, the last figure should be corrected for the arbitrary choice of t_0(Baksan) = -29.5 s.

Feb/23/1987 at 7:35 UT



$T_{IMB} - T_{KAM} = 7.7$ sec

$T_{IMB} - T_{BAK} = -30.4$ sec

LSD			Kamiokande				
Event Number	Time	Energy (MeV)	Event Number	Time	Nhit	cos(teta)	Time dif.(sec) LSD-Kam
957	2:11:37.04	6.4	124037	2:11:29.72	23	-0.647	7.31
970	2:29:30.77	7.5	124948	2:29:23.39	21	-0.807	7.37
971	2:31:23.31	6.8	125041	2:31:16.51	20	-0.805	6.80
979	2:36:17.75	6.5	125275	2:36:10.91	20	0.170	6.84 ← BST
1017	3:05:35.37	7.1	126600	3:05:28.82	34	-0.028	6.55
1026	3:12:39.10	7.2	126905	3:12:32.57	21	-0.842	6.53
1027	3:12:39.46	7.3	.	.	.	.	6.89
1040	3:28:33.18	7.2	127782	3:28:25.99	39	-0.845	7.19
1044	3:31:06.14	5.5	127904	3:30:59.18	21	0.321	6.96

Coincidences between LSD and K2 in the period from 1:45 - 3:45 UT, Feb. 23 1987.
The coincidence window is ± 0.5 sec.

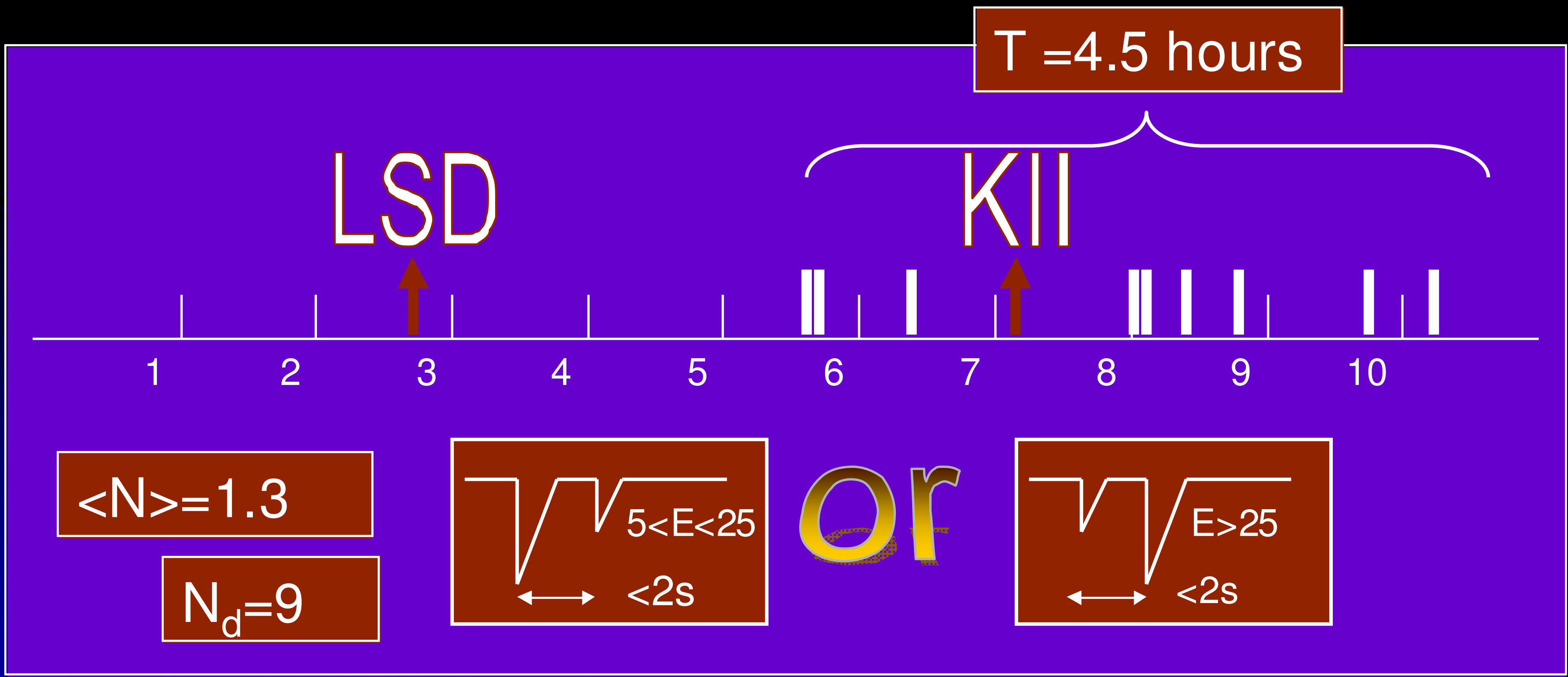
LSD				Baksan		
Index	Event Number	Time	Energy (MeV)	Time	Energy (MeV)	Time dif.(sec) LSD-Baksan
1 2 3 4	931	1:47:48.80	8.4	1:48:18.12	22.9	-29.32
1 3 4	934	1:52:22.45	6.3	1:52:52.63	17.5	-30.18
1 2 3 4	945	2:03: 0.48	7.9	2:03:30.04	8.8	-29.56
1 2 3 4	954	2:10:40.10	6.2	2:11:09.70	35.6	-29.60
1 2 3 4	955	2:10:40.32	6.8	•	•	-29.38
2 3	962	2:17: 5.05	7.2	2:17:33.84	22.9	-28.79
2 3 4	966	2:22:31.19	7.5	2:23: 0.33	12.5	-29.14
1 3 4	968	2:26:42.26	7.4	2:27:12.49	35.9	-30.23
1 2 3 4	977	2:34:35.62	6.9	2:35: 5.00	19.2	-29.38
1 3 4	979	2:36:17.75	6.5	2:36:47.80	29.1	-30.05 ← K-II
1 2 3 4	981	2:38:24.89	7.8	2:38:54.41	24.7	-29.52
1 2 3 4	036	3:25:15.53	7.0	3:25:45.11	23.5	-29.58
2 3 4	1047	3:38:21.10	7.8	3:38:50.08	20.6	-28.98
4	1051	3:43: 3.69	6.9	3:43:34.09	22.1	-30.40

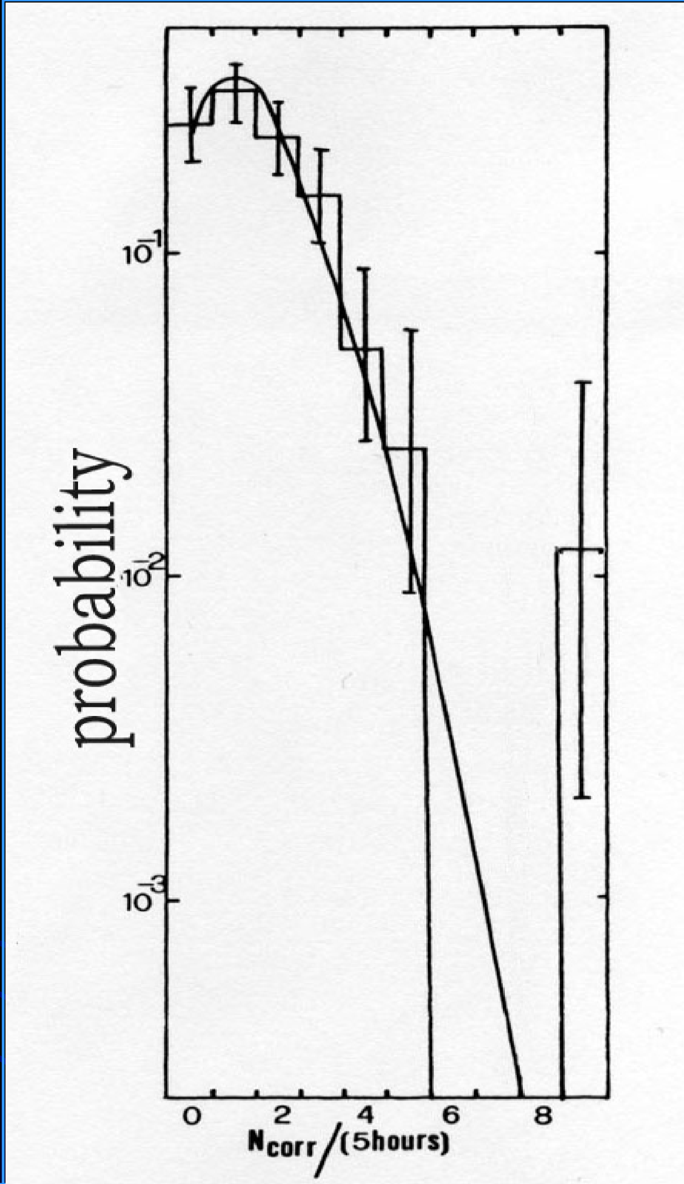
Coincidences between LSD and BST in the period from 1:45 UT to 3:45, Feb. 23 1987.
The meaning of the index is:

Index	Coinc.window (sec)	BST time shift (sec)
1	± 0.5	-29.8
2	± 0.5	-29.1 o -29.2
3	± 0.75	-29.5
4	± 0.75	-29.7

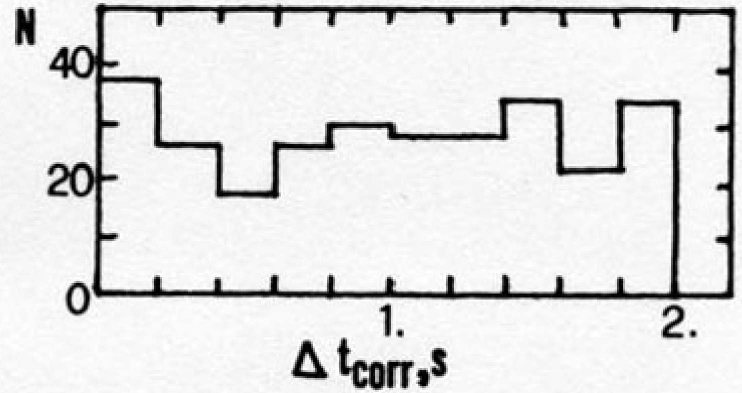
KII

№	Time UT±1min	E, MeV	Theta, degree
1	2:52:34	5.3	59
2	37	5.8	47
3	40	11.4	15
4	2:52:44	4.8	130

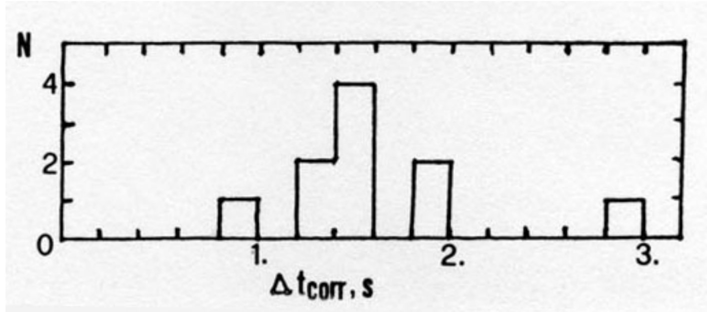




The probability distribution of the counting rate of pairs of correlated pulses per 5 hours and the poissonian fit to this distribution; $<n_{corr}>=1.46/(5$ hours), $\Delta T=2$ s



The distribution of time differences between the pulses in the pairs ($\Delta t=2$ s) for the whole data set excluding the interval of interest



For 10 pairs ($\Delta t=3$ s) from 5:42 UT to

9 pairs ($\Delta t=2$ s)

10:13UT on February 23, 1987 .

Phase D

Correllations between BST - IMB LSD – IMB and GW antennas

ASTRONOMY

Another mystery from the supernova

New data defy explanation but must mean *something*

By David L. Chandler
Globe Staff

What may be the greatest mystery yet about last year's supernova explosion in the southern skies, which has already produced a variety of puzzling effects to give theorists headaches, was reported at Tufts University last week to the consternation of an international gathering of physicists.

The new analysis of data collected by several instruments on the day of that stellar explosion suggests that the death throes of the distant star were incredibly complex, continued over a long span of time, and may have resulted in the emission of particles of a previously unknown type.

This analysis has drawn reactions ranging from bewilderment to outright skepticism from scientists who have been studying the supernova.

Data from the day in February 1987 when the supernova flared into view – data that most scientists had wanted to throw out and forget because they seemed to make no sense – turn out to contain "coincidences" so unlikely that they could mean something, some scientists said last week at the 13th annual International Conference on Neutrinos and Astrophysics, held at Tufts.

But as to just what these coincidences might mean, nobody seems to have a clue; No theory can yet account for the observations – if they are real.

The observations come from at least four instruments in different parts of the world: huge underground tanks of liquid lined with light detectors, in France and Japan, designed to pick up the tracks of passing neutrinos, which are incredibly elusive subatomic particles; and large cylinders of aluminum in Rome and Maryland designed to detect gravity waves, a

SUPERNOVA, Page 33

They defy explanation but must mean *something*

SUPERNOVA
Continued from Page 31

kind of radiation physicists believe must exist but which has never been detected.

Data from these independent devices show that several times over a two-hour period just before the supernova was discovered, something happened at all four places almost simultaneously.

"Eleven or more times during two hours, supernova 1987A emitted a brief pulse of 'neutrinos' arriving just after a brief pulse of 'gravity waves,'" said Alvaro De Rujula, a physicist at CERN, the European Center for Nuclear Research, in a presentation to the Tufts neutrino conference.

The coincidences were discovered by physicist Guido Pizzella of the University of Rome, and De Rujula has been analyzing the probabilities involved and trying to find an explanation for the findings. The odds against these "coincidences" being the result of chance are a million to one, De Rujula has calculated.

But there are serious problems, he quickly pointed out. If the pulses that showed up on the gravity wave detectors were in fact caused by gravity waves, they are one million times more energetic than predicted by theory. Similarly, if the neutrino detectors were in fact picking up neutrinos, they were 100 times more energetic than expected.

That's why De Rujula insisted on putting the words "gravity waves" and "neutrinos" in quotes. He is convinced that *something* real was happening, but that it must have been something other than gravity waves and neutrinos.

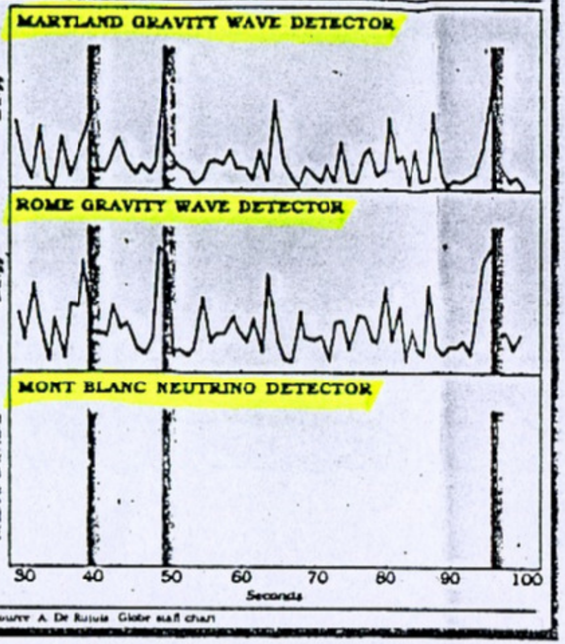
"What the gravity wave detectors have seen are not gravity waves," he said. He suggested, instead, that they were picking up the tracks of a new and unknown kind of particle, "scalar particles" similar to the hypothetical "gravitons" that are believed to carry the force of gravitation.

But De Rujula, who is also a professor of physics at Boston University, concedes he is unable to explain all the findings. Scalar particles could account for the "gravity wave" detections, but it is much more difficult to explain the excessive energy of the "neutrino" detections.

"Alternatives to neutrinos are very contrived," De Rujula wrote in his paper on the findings, "and introducing more than one wild hypothesis per paper is bad manners."

Triple coincidences at the time of the supernova explosion

Instruments in three places picked up 3 simultaneous pulses from the supernova in this brief time span. Other such "coincidences" were seen over a two-hour period.



Source: A. De Rujula Globe staff chart

But the lack of an explanation doesn't mean the data can simply be ignored, De Rujula said. The coincidences are so improbable that they must mean *something*.

"Having a four-way coincidence like this is just amazing," commented Lawrence R. Sulak, chairman of the physics department at Boston University. "This is going to be a big one. Usually you have some theories" to try to account for new findings, but in this case "there's no obvious explanation. It's a great mystery."

But he said it "looks like pretty solid work," and the improbability of the coincidences make them hard to ignore.

Even some of those skeptical of the findings – and they are the majority – were impressed by the quality of De Rujula's statistical analysis of the data.

The analysis was "brilliantly implemented," said Sheldon Glashow, Harvard University physicist and Nobel laureate, who described De Rujula's presentation as "the most fascinating talk of the meeting."

But Glashow called it "a very strange situation, where he's taking the results of a lot of experiments that are all weak in themselves and stitching them together into a masterful silk purse that seems to indicate something new going on."

The detections are considered weak by many scientists because the level of energy recorded is very close to – in some cases less than – the "background" level seen in these devices. In the gravity wave detectors, this background noise consists of random vibrations caused by temperature differences in the aluminum, as well as electrical noise in the circuits that monitor the antennas.

In neutrino detectors, noise can come from radioactivity in the walls of the huge underground fluid-filled chambers where the detectors are located. There are also a certain number of random, background neutrinos from space that pass through the chambers every day.

Glashow said "I'm skeptical," but added that "it's slightly tantalizing. Tantalizing, yes; but convincing, no."

There are three problems in reconciling the correlations with theories of how supernovas are supposed to act:

- The excessive energy of the "gravity waves," which would make sense only if the star were a million times the size of the sun – an impossibility.
- The excessive energy of the "neutrinos," 100 times greater than predicted by theory, which may be the most difficult to explain.
- The long duration in which the coincidences are seen – about two hours – which suggests it took that long for the star to collapse in a series of hiccups or convulsions.

A supernova occurs when a star has burned all of its nuclear fuel, and collapses under its own weight. In doing so, it spews out most of its remaining matter and emits an intense burst of neutrinos, and the matter that remains forms a super-dense object called a neutron star or a black hole.

Most scientists had believed the collapse of a star of the type that produced this supernova should have taken place in a few seconds. But if these coincidences are real and not just chance correlations of background noise, the star's death must have been "surprisingly long and convulsive," De Rujula said.

Stars heavier than the one that produced supernova 1987A "have been numerically found to have long and convulsive agonies," according to De Rujula. "Before final collapse, the core suffers various violent pulsational instabilities."

But for a star of the type believed to have produced this supernova, "a similar pyrotechnical death over a period of hours would most certainly come as a surprise."

But Sulak said according to some theories, a star 25 times as heavy as the sun "definitely does have oscillations at the right time scale." He said some Soviet physicists have constructed models that show "it breaks up into pieces and radiates for that period of time."

"There's a real dearth of information," he added. "We're just groping. This is our first observational information from a supernova in our technological lifetimes."

The next step is to look for the same events in two other neutrino detectors that also detected pulses of neutrinos from the supernova: The IMB detector under Lake Erie, and the Baksan detector in the USSR. The Soviets have not yet published their data, but the IMB data is now being studied.

Sulak, who designed the IMB detector, said last week, "Once we've done our work" of comparing the IMB data with the other four sets, "if we see a correlation we'll be dumbfounded." A five-way coincidence would make the possibility the results are caused by chance even more unlikely.

But many physicists insist the coincidences are so outlandish that they simply cannot be believed.

"Those of us who have lived with astrophysics for 20 years are used to seeing things come and go," said astronomer Kenneth Brecher of Boston University, pointing out that many seemingly dramatic findings have simply not stood up to the test of time. "I choose to believe this data is so anomalous it's probably not associated with the supernova. I choose to ignore it. the most important 20th century science it's highly unlikel case."

De Rujula agreed cidences might hav something other th nova, and said he " the whole picture. that one piece work up to anything." Bu improbability is so g implications so imp findings do turn ou that "one should lo before throwing it think that it should

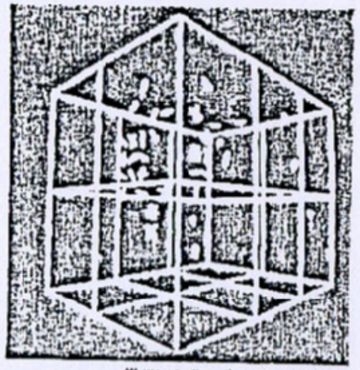
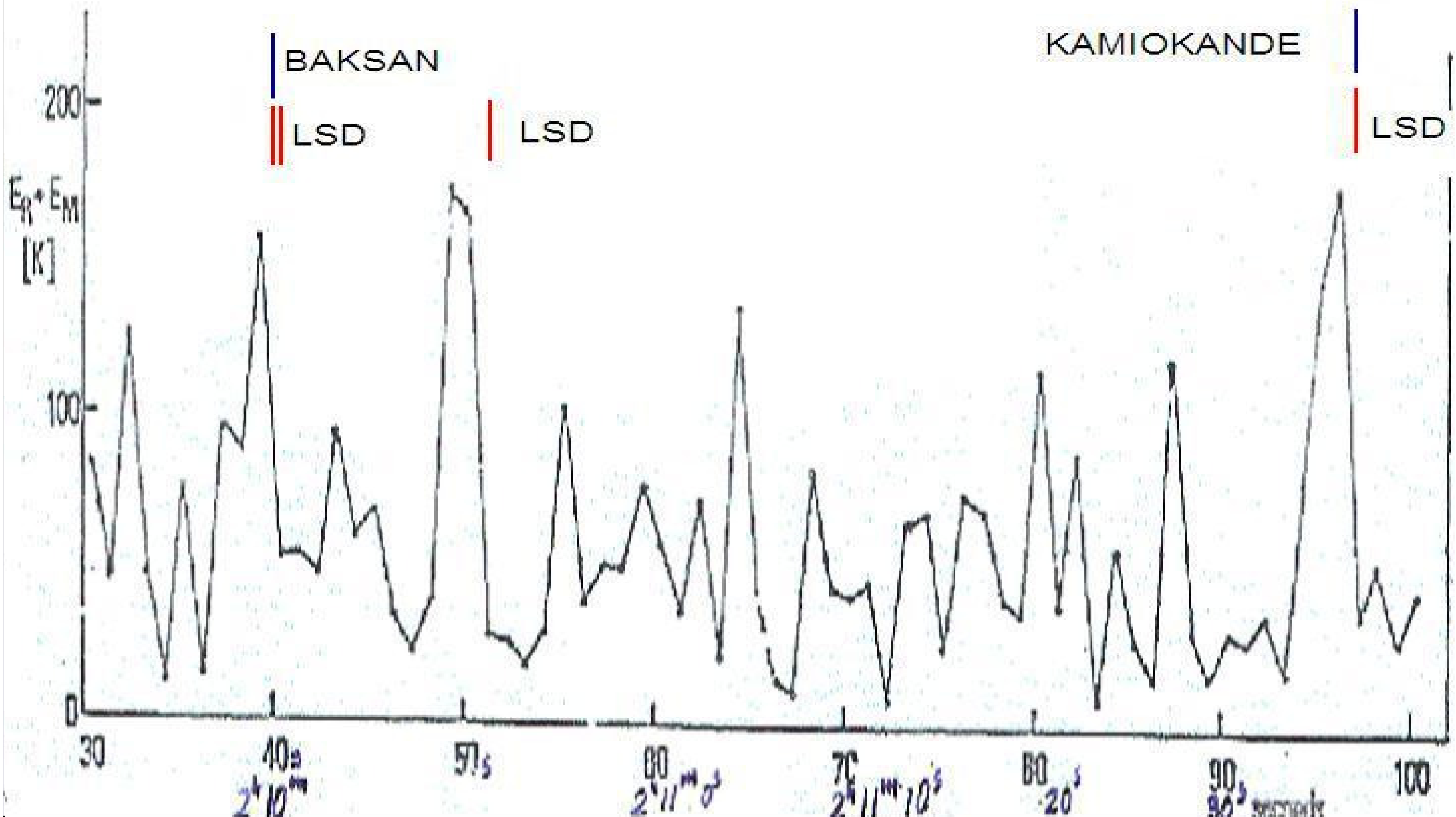


Photo courtesy/Lawrence R. Sulak

Neutrino from supernova strikes IMB detector, producing circle of light (stars) on wall of 50-foot water tank.

N.Y. Times
6/13/88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Professor F.Raines
University of California
Department of Physics
Irvine, California 92717
USA

15 March, 1990

Dear prof. Reines,

By this letter I would like to draw your attention to the crazy busness concerning correlations between underground detectors data 23 Feb. 1987 prior to SN1987A. My personal connection (and attitude) to the subject was formulated in my talk at Texas Symposium at Dalla Dec. 1988 (ref.1)(I enclose the paper). After Dallas during my stay at Irvine R.Svoboda, d.Kielczewska and myself tried to look if there is any correlation between LSD(Mont Blanc) and IMB data similar to LSD x Baksan correlation and found none. As I remember at that stage of analysis we tried to select the small energy IMB events (small number of hits). More complete results are presented in 21 ICRC Proc vol.10,p.40(Ref.2).

Meanwhile people at Baksan lab. E.N.Alexeev and I.M.Kogai have found some correlation between LSD or Baksan neutrino-like low energy events and high energy Baksan events looking like muon induced cascades or horizontal muons-Pisma JETP vol.49,N9,p.480,1989(Ref.3).

The signal was not very strong but it gave them the idea to try also high energy IMB events. A remarcable correlation was observed between LSD and those IMB events wich have been identified as horizontal muons.

To evaluate the significance of this result I suggest the following procedure:

1. First of all avoid the temptation to ajust the parameters involved in analysis as time period T, time gate Δt or time shift specifically to correlaton with IMB. Let us use the same parameters as in (ref.1) which certainly are independent on IMB data.

2. Let us select for the testing IMB those LSD events, which arrived in the period 1:45 ÷ 2:45 in coincidence with GA(gravitational an-

Table 2.

		IMB-tot N=8084	IMB- N=6340	IMB 70° N=317
1.	LSD x (BC+GA) N=13	72/58,8 $5{,}5\cdot10^{-2}$	61/46,1 $2{,}1\cdot10^{-2}$	11/2,31 $3{,}0\cdot10^{-5}$
2.	LSD x BC N=10	58/45,4 $4{,}1\cdot10^{-2}$	49/35,6 $1{,}9\cdot10^{-2}$	9/1,72 $1{,}0\cdot10^{-4}$
3.	LSD x GA N=7	40/31,9 $9\cdot10^{-2}$	35/25,01 $3{,}5\cdot10^{-2}$	6/1,25 $1{,}8\cdot10^{-3}$
4.	LSD x BC x $\widetilde{GA}$ N=6	32/26,2 $15\cdot10^{-2}$	26/21,1 $17\cdot10^{-2}$	5/1,06 $4{,}6\cdot10^{-3}$
5.	LSD x BC x GA N=4	26/18,4 $5{,}5\cdot10^{-2}$	23/14,4 $2{,}3\cdot10^{-2}$	4/0,72 $6{,}4\cdot10^{-3}$
6.	LSD N=43	214/198 $13\cdot10^{-2}$		
7.	BC N=116	545/516 $10{,}0\cdot10^{-2}$		

I believe that the data in table 2 shows an another independent support of the reality of the fantastic phenomenon in question. It is difficult to evaluate some confidential level, but I suppose that the probability to have such evidence just by chance is less than 1%, If so the statement in ref.2 concerning the absence of significant correlation between IMB and LSD-Baksan probably should be corrected.

I suggest three things:

1. To look into the data more thoroughly.
2. If the evidence will be confirmed - think about the publication of the results in spite of its unbelievable and fantastic meaning.
3. It seems very important to look for the Kamiokande high energy events, specifically horizontal muons. Unlike with IMB there is though a quite small but positive correlation with my algorithm of a neutrino - like Kamiokande signals - 2 when 0,6 expected. No serious disagreement with IMB really. But the muon - like events can be crucial. We do not have them. What do you think about going in touch with Koshiba or Totsuka? In Dallas I made no success asking Al.Mann of more complete Kamiokande data.

I am sending the copy of this letter to R.Svoboda and O.Saavedra and hope you will be able to discuss the subject with D.Kielczevska or others involved whom I do not know .

Hoping to hear your advice concerning the matters discussed.

Yours sincerely

A.E.Chudakov

Conclusions

- LSD detected on real time a burst of 5 signals at 2:52:36 before optical observation.

  Means this signal the first bang of the SN1987a?

  Can two bangs or rotated SN star model explain this effect?

- LSD detected one pulse at the IMB-K-II time

  LSD was the unique that give a prediction about the SSN ν's

- A series of coincidences have been found among LSD-Kamiokande-Baksan underground detectors in a period encompassing 1.5-2.0 hrs the Mt. Blanc burst.

Are the LSD, Kamioka, Baksan pulses real one?
The "phantastic effect", as is called by Chudakov, are something to do with the SN1987a?
If it is so, what they are?

Dear Russian Friends

After this long and wonderful Italy-Russian collaboration during more than 30 years, I would like to express all my deep heart with only one word:

Спасибо