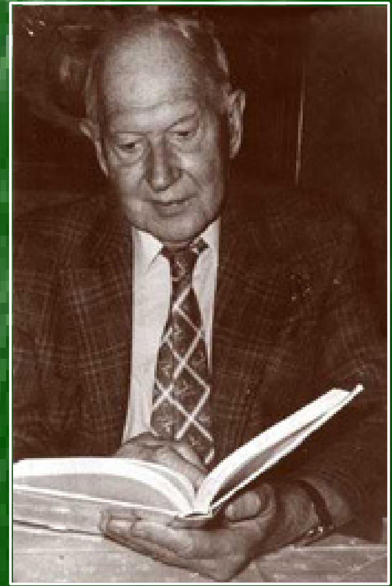
V Марковские чтения

10 - 11 мая 2007 г. Москва

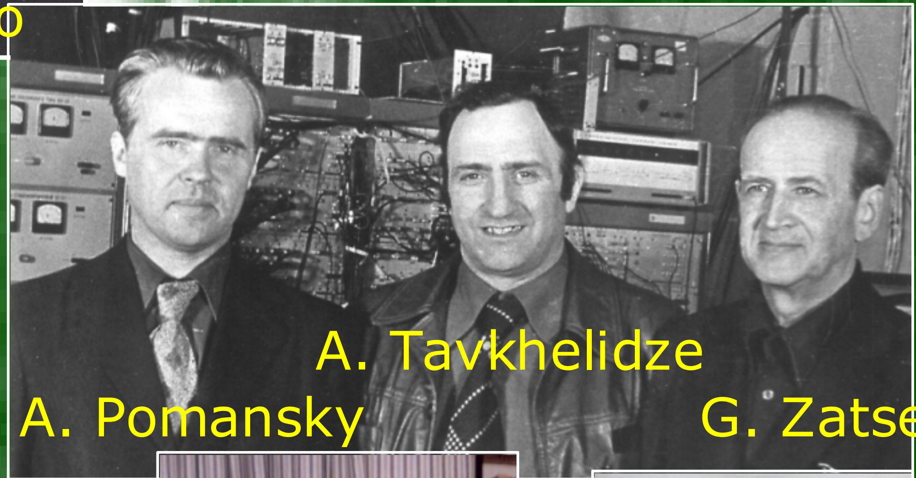


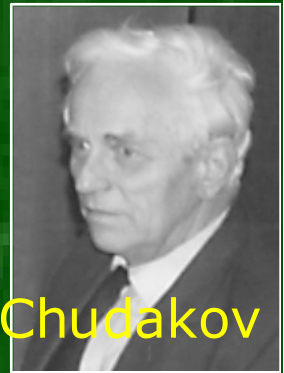
Проблема нейтринного излучения от SN 1987A. Двадцать лет спустя.

Problems of Neutrino Radiation from SN 1987A 20 years later

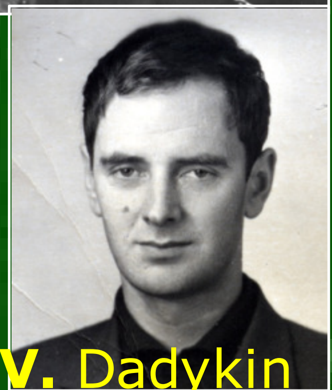
О.Г. Ряжская

1963 – decision for constructing underground neutrino laboratory to study solar neutrino, atmospheric neutrino and … at Baksan valley. Creation of the neutrino laboratory (FIAN, from 1971 INR AS of the USSR)





1965 – elaboration of new liquid scintillator: transparency L~50m, stability >40 years, <u>the price 30 kop/L (<30cent/L.)</u>



1965-80 – study of cosmic ray background

1979 - first detection of up-going atmospheric neutrino in Baksan.

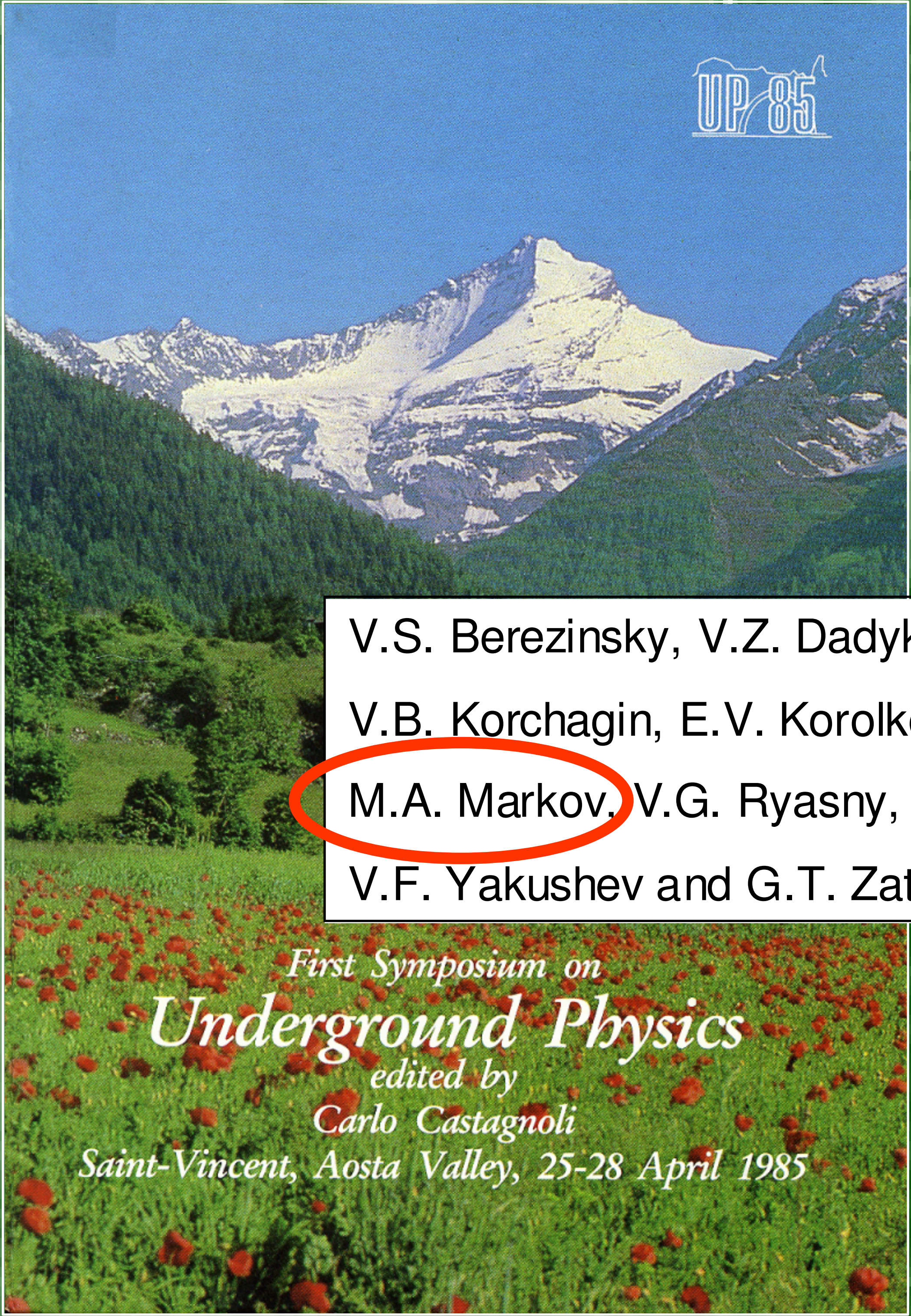
1979-80 – the beginning of search for neutrino from collapsing stars in Arteomovsk and Baksan. 3 detectors used the liquid scintillator.

- *Discussion about underground physics, 1969.*

- *Discussion about Russian-Italian collaboration, 1977.*

Mont Blanc

детекторы разгружены



The Large-Volume Detector (LVD) of the Gran Sasso Laboratory.

C. Alberini, G. Bari, M. Basile, G. Cara Romeo, A. Castelvetri, L. Cifarelli, A. Contin, C. Del Papa, D. Galli, G. Iacobucci, G. C. Maccarrone, T. Massam, F. Motta, R. Nania, R. Odorico, G. Prisco, G. Rinaldi and G. Sartorelli

Istituto Nazionale di Fisica Nucleare - Sezione di Bologna

G. Barbagli and P. G. Pelfer

Dipartimento di Fisica dell'Università - Firenze

R. Casaccia, I. Laasko, A. Rindi, G. C. Susinno and L. Votano

LNF-INFN - Frascati

F. Cardone, G. Di Sciascio and R. Scrimaglio

Dipartimento di Fisica dell'Università - L'Aquila

V.S. Berezinsky, V.Z. Dadykin, F.F. Khalchukov, P.V. Korchagin, V.B. Korchagin, E.V. Korolkova, V.A. Kudryavtsev, A.S. Malgin, M.A. Markov, V.G. Ryasny, O.G. Ryazhskaya, V.P. Talochkin, V.F. Yakushev and G.T. Zatsepin

R. Meunier, F. Rohrbach and A. Zichichi

CERN - Genève

V. S. Berezinsky, V. Z. Dadykin, F. F. Khalchukov, P. V. Kortchaguin, V. B. Kortchaguin, E. V. Korolkova, V. A. Kudryavtsev, A. S. Malguin, M. A. Markov, V. G. Ryassny, O. G. Ryazhskaya, V. P. Talochkin, V. F. Yakushev and G. T. Zatsepin

Institute for Nuclear Research of the Academy of Sciences of USSR - Moscow

(ricevuto il 12 Agosto 1985)

SN 1987A
23 February 1987

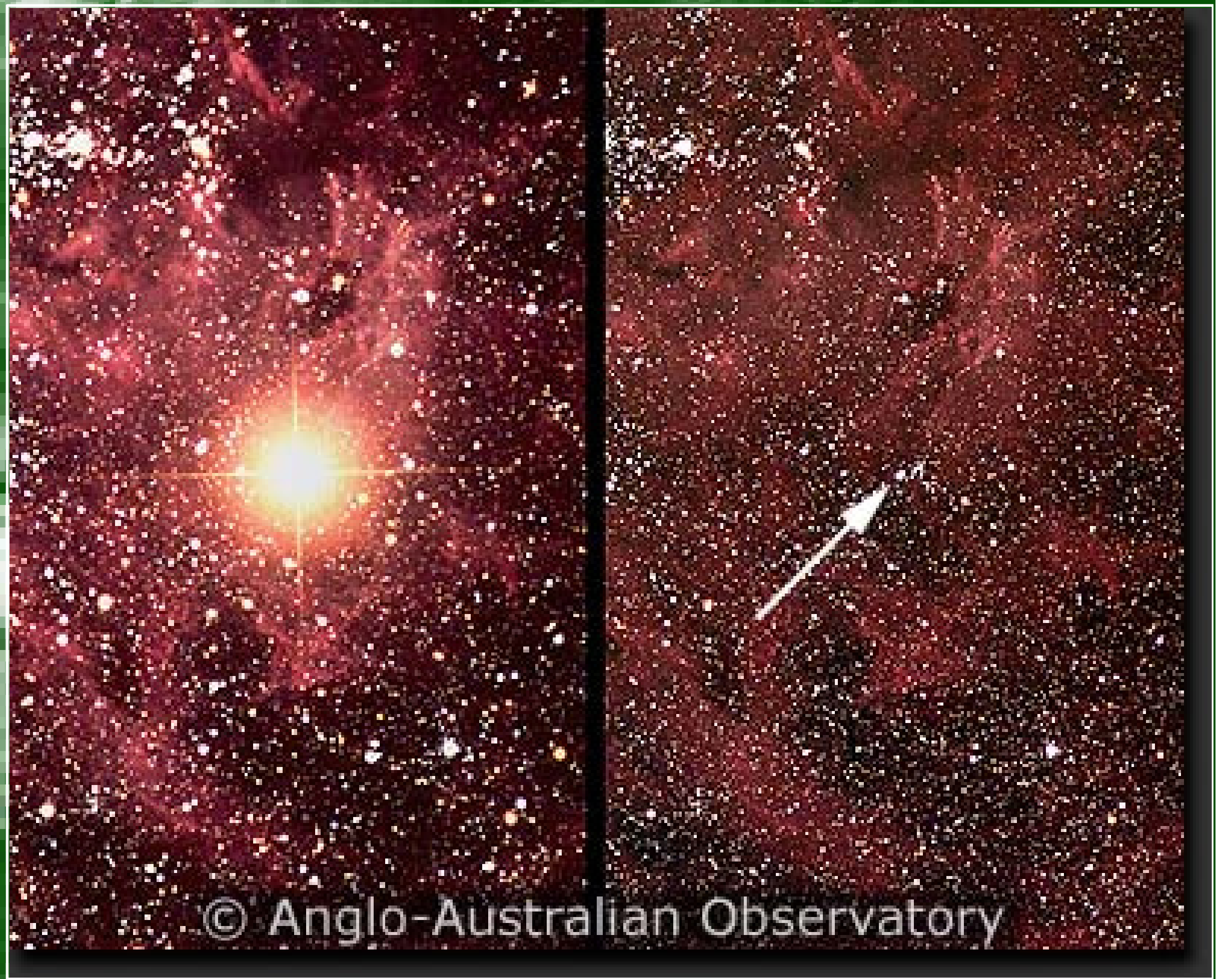
What was seen in underground neutrino detectors?

What were the questions on the neutrino detection at that time?

What are the answers on that now after 20 years?

Possible explanation of the results, obtained by underground detectors during Supernova SN1987A explosion.

The name "SN" came from the observational astronomy data and deals with an instant appearance of a very bright star, with luminosity of about tens billions of the solar one.



$$\left.\begin{array}{l} {}_{Z}N^{A} + e^{-} \rightarrow {}_{Z-1}N^{A} + \nu \\ {}_{Z-1}N^{A} \rightarrow {}_{Z}N^{A} + e^{-} + \tilde{\nu} \end{array}\right\}$$ URCA-process

$$p + e^{-} \rightarrow n + \nu_{e}$$

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

The idea was born in Rio casino "Urca" where it was possible to lose a lot of money very quickly.

1941 *«We have developed the general views regarding the role of neutrino emission in the* ***vast stellar catastrophes*** *known to astronomy, while the neutrinos are still considered as highly hypothetical particles because of the failure of all efforts made to detect them».*

G.Gamov, M.Schoenberg

1965 Ya. B. Zel'dovich and O. H. Guseinov show, that gravitational collapse is accompanied by powerful and short (~10 ms) pulse of neutrino radiation.

1965 The first proposal to search for collapsing starts (c.s.) using neutrino detectors by G. V. Domogatsky and G.T. Zatsepin

1965 *The birth of an experimental neutrino astrophysics*.

1964-1966 W. Fowler, F. Hoyle investigate the role of neutrinos in the last stages of stellar evolution. The dissociation of iron core plays an important role in stability loss by massive stellar envelopes.

1966 The first calculation of collapse dynamics by S. Colgate, R.White

1966-1967 The process of an implosion for stars with 32; 8; 4; or 2 solar masses has been studied. The parameters of neutrino radiation are obtained (W. Arnett).

1967-1978 The structure of neutrino burst , υ_e and $\tilde{\upsilon}_e$ energy spectra was studied by V.S.Imshennik, L.I.Ivanova, D.K.Nadyozhin, I.V.Otroshenko (Model I) at the first time . Also it was shown that the main flux of the neutrinos is emitted during the cooling stage of a new born neutron star. The duration of neutrino pulse was shown to be ~ 10 s.

1980-1982 The time structure and energy spectra of $\tilde{\upsilon}_e, \upsilon_e, \upsilon_\mu, \upsilon_\tau$ for the initial stage of collapse (<0.1 ms) are obtained by R.Bowers, J.Wilson (Model II).

1987 S. Bruenn's calculations

Neutrino detection from a collapsing star makes it possible:

-To detect gravitational collapse even it is “silent” (isn’t accompanied by Supernova explosion);
-To investigate the dynamics of collapse;
-To estimate the temperature in the star center.

If the star is nonmagnetic, nonrotating, spherically symmetrical the parameters of neutrino burst are the following (Standard model):

Model	Total energy, $10^{53} erg$	Total energy of $\tilde{\nu}_e$, $10^{53} erg$	Total energy of ν_e, $10^{53} erg$ neutronization stage, t=3*10-2 sec	$\bar{E}_{\tilde{\nu}_e}$, MeV	$\bar{E}_{\nu_e}$, MeV	$E(\nu_e)$ MeV	Duration, s
Model I	3-14	0.5-2.3	0.1	12.6	10.5	-	~20
Model II				10	8	25	5

From the theory of the Standard collapse it follows that the total energy, carried out by all types of neutrinos $\nu_e, \tilde{\nu}_e, \nu_\mu, \tilde{\nu}_\mu, \nu_\tau, \tilde{\nu}_\tau$, corresponds to ~ 0.1 of star core mass and is divided among these 6 components in equal parts.

General idea

How can one detect the neutrino flux from collapsing stars?

Until now, **Cherenkov (H_2O)** and **scintillation (C_nH_{2n})** detectors which are capable of detecting mainly $\tilde{\nu}_e$, have been used in searching for neutrino radiation, This choice is natural and connected with large $\tilde{\nu}_e$-p cross-section

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

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

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

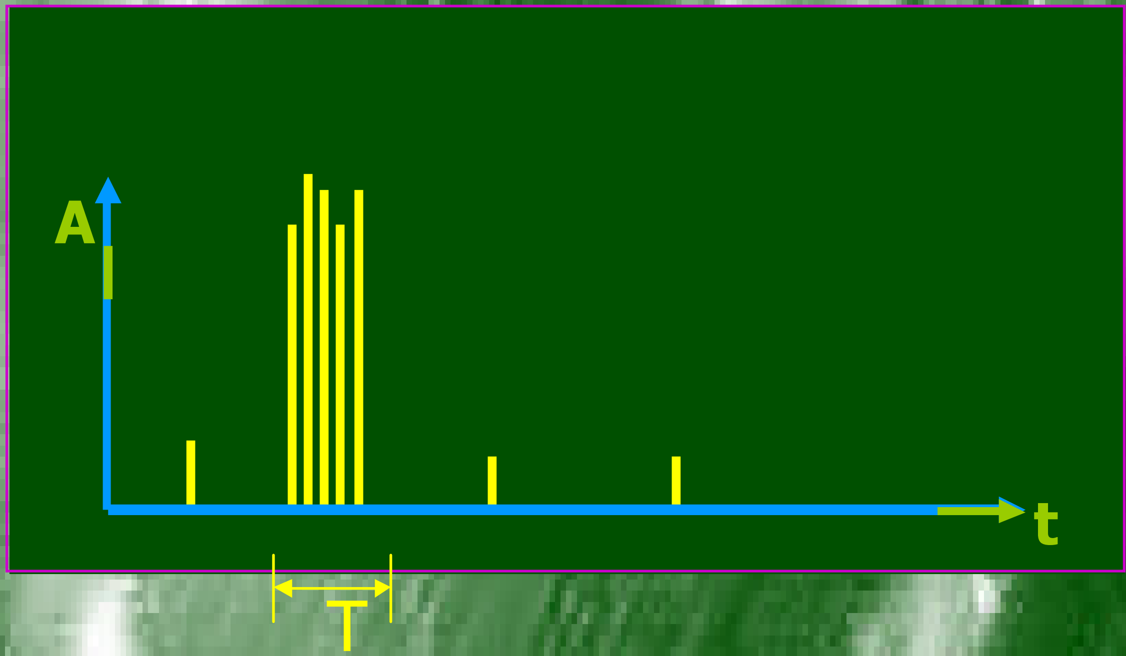
As was shown at the first time by G.T.Zatsepin, O.G.Ryazhskaya, A.E.Chudakov (1973), the proton can be used for a neutron capture with the following production of deuterium (d) with γ - quantum emission with τ~180 – 200 μs.

$$n + p \rightarrow d + \gamma \ 1$$

$$E_\gamma = 2.2 \ MeV$$

The specific signature of event

How can the neutrino burst be identified ?



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

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

The possibility to observe the neutrino burst depends on background conditions

The source of background:

1. Cosmic rays $0<E<\infty$
   a) muons
   б) secondary particles generated by muons (e,γ,n and long-living isotopes)
   c) the products of reactions of nuclear and electromagnetic interactions
2. Natural radioactivity E<30 MeV, mainly E<2.65 MeV
   a) γ,
   b) n, (n γ), U^{238}, Th^{232}
   c) α, (αn) d) Rn^{222}

Background reduction:

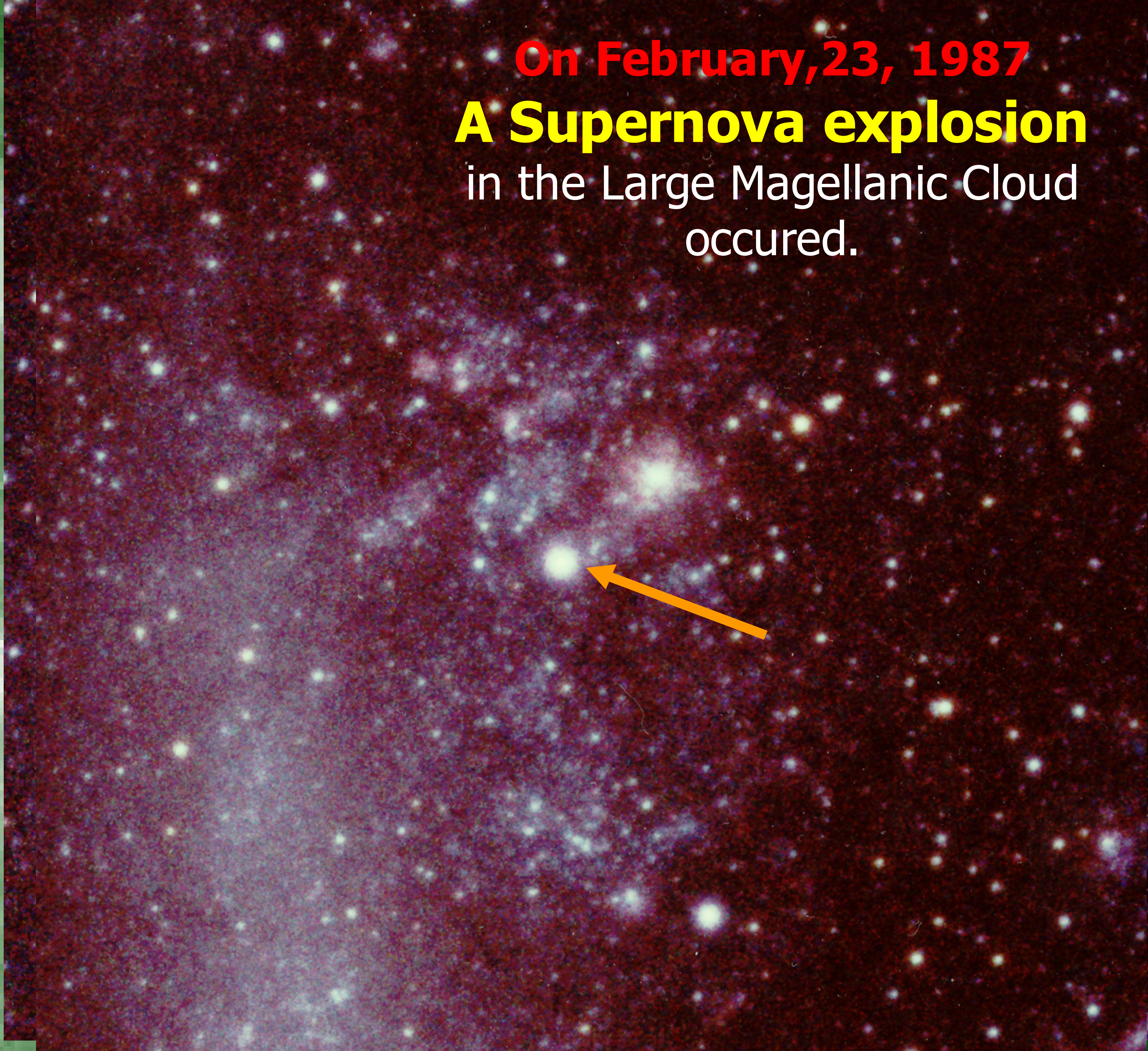
1. **Deep underground location**
2. **Using the low radioactivity materials**
3. **Anti-coincidence system**
4. **Using the reactions with good signature**
5. **The coincidence of signals in several detectors**

On February,23, 1987

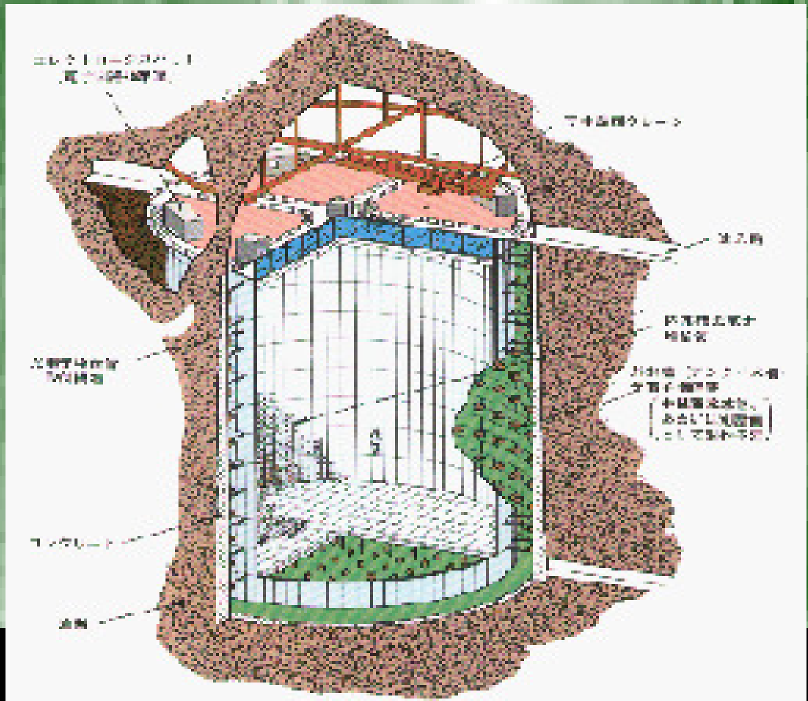
A Supernova explosion

in the Large Magellanic Cloud

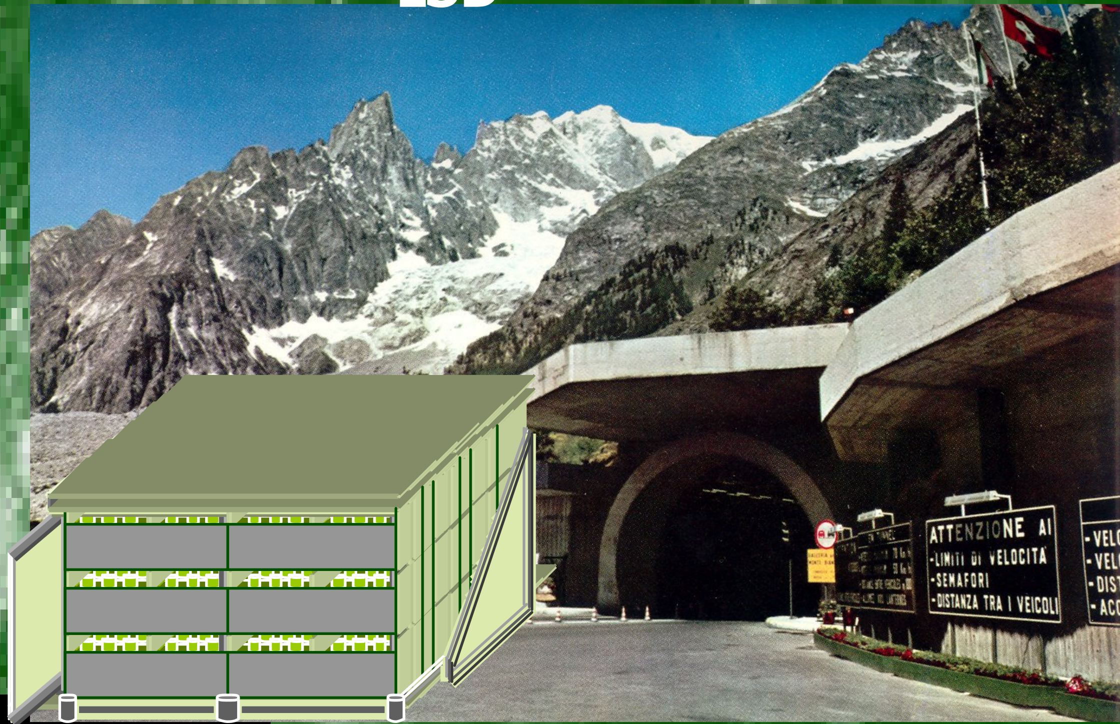
occured.

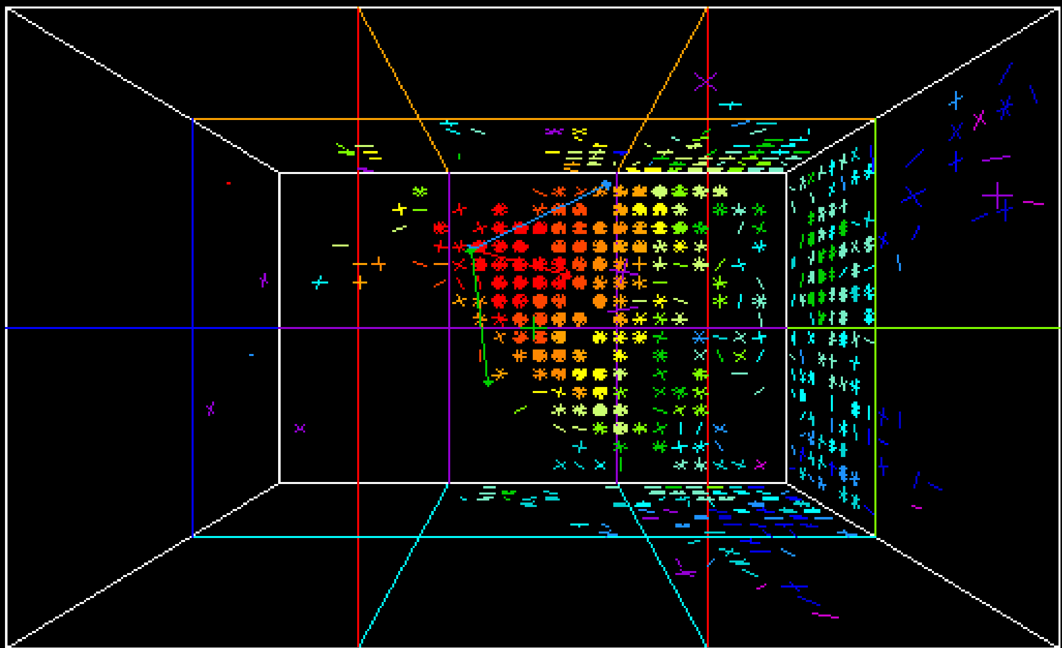


Kamiokande



LSD



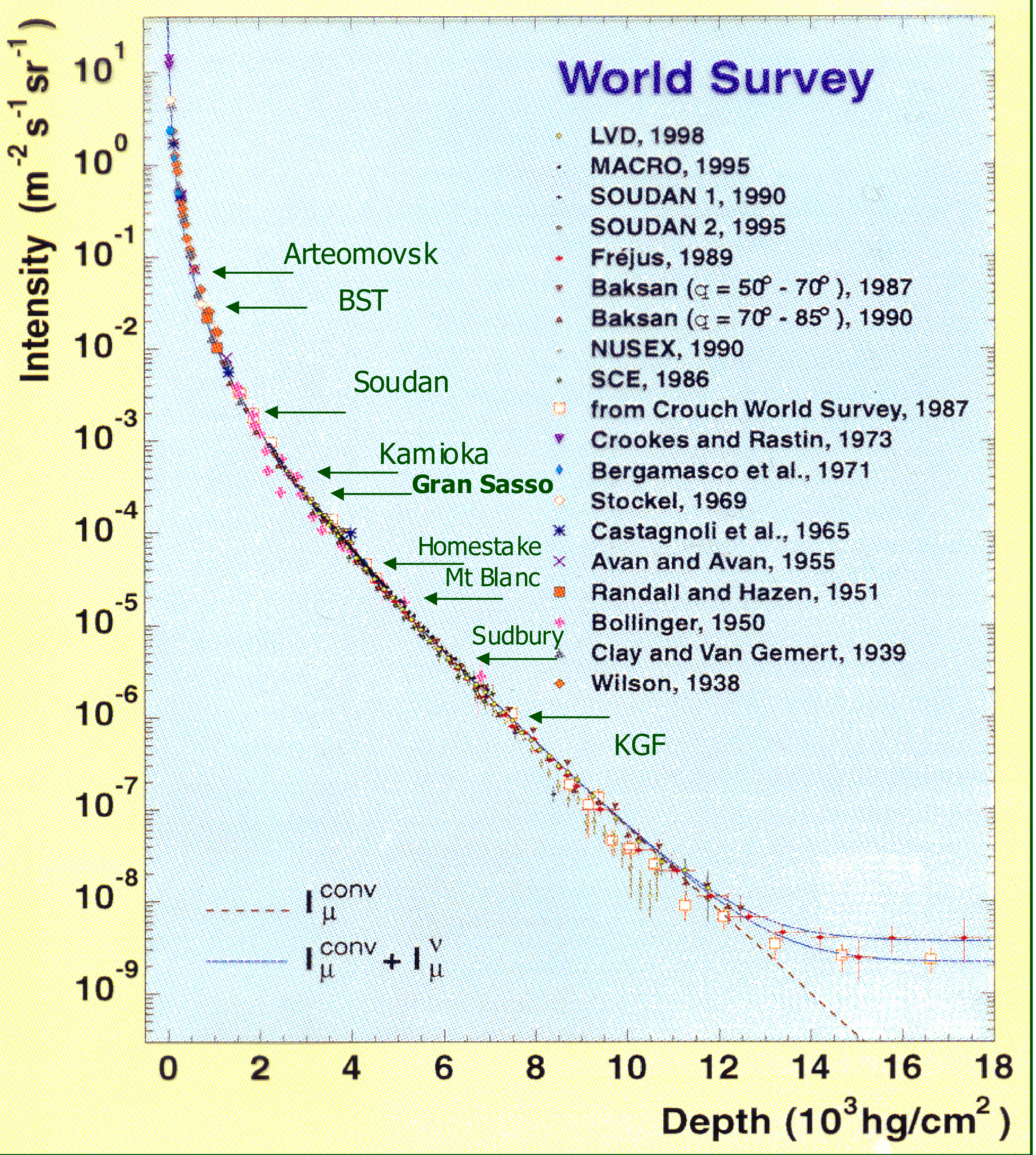


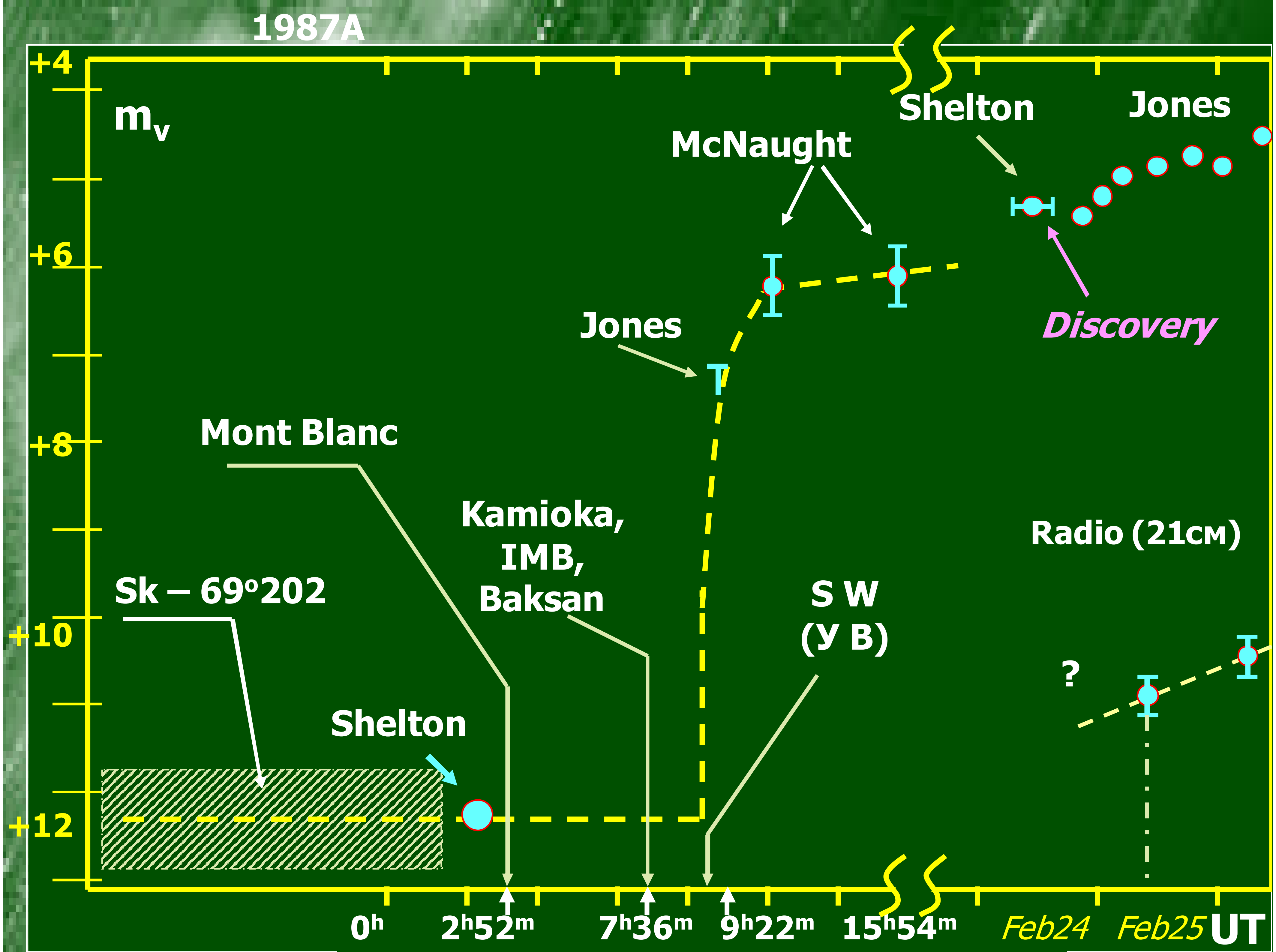
IMB

Баксан

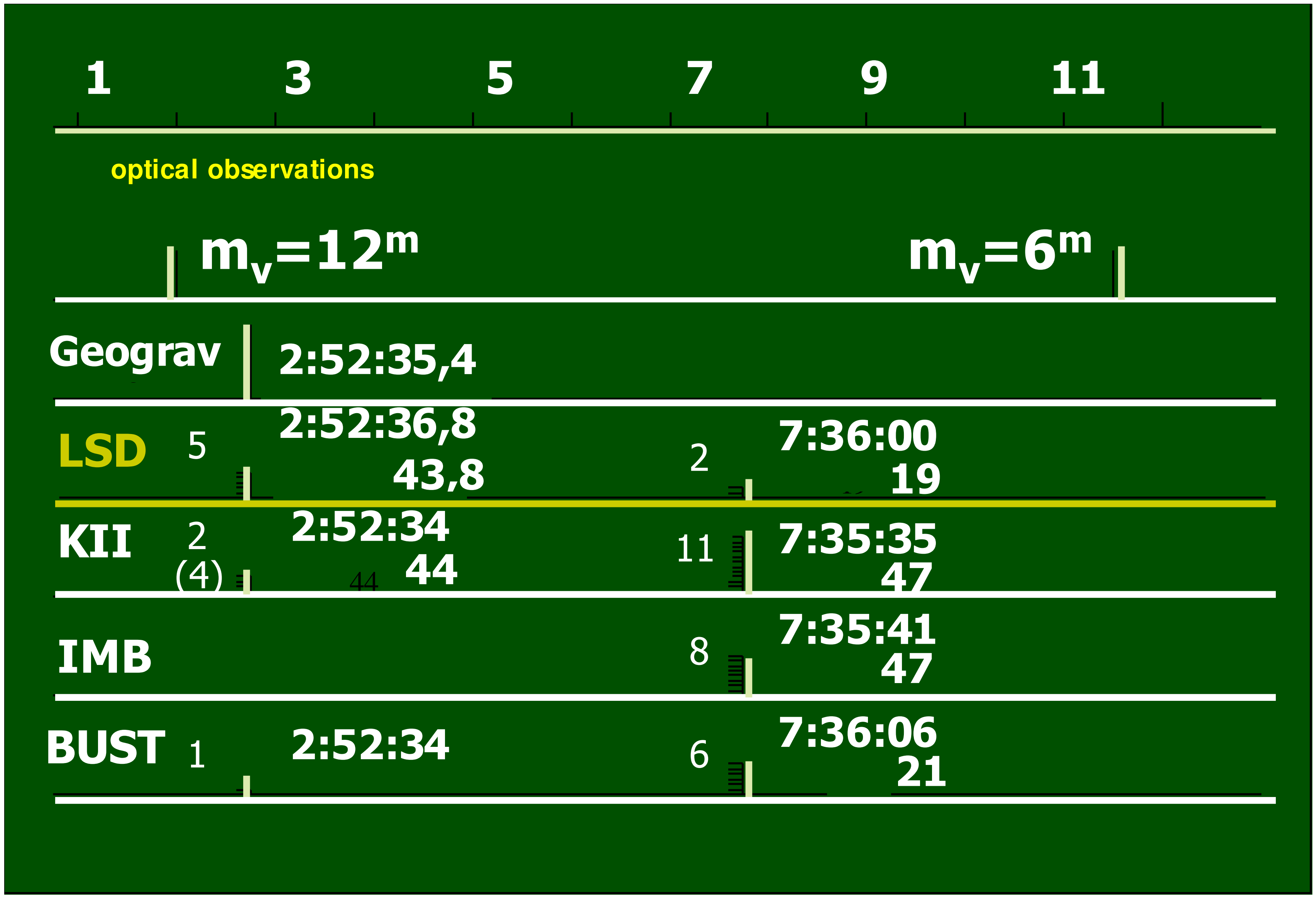
Detector	Depth, meters of water equivalent	Fiducial volume, tons	Material	Energy threshold, MeV	Detection efficiency		Background rate s^{-1}
					e^+ spectrum of reaction $\tilde{\nu}_e p \rightarrow e^+ n$	e^- spectrum of reaction $\nu_i e^- \rightarrow \nu_i e^-$	
BUST USSR	850	130 (200) 160	C_nH_{2n} Fe	10	0.6	0.15 (0.54)	0.013 (0.033)
LSD USSR – Italy	5200	90 200	C_nH_{2n} Fe	5-7	0.9	0.4(0.7)	0.01
KII Japan – USA	2700	2140	H_2O	7-14	0.7	0.17 (0.54)	0.022
IMB USA	1570	5000	H_2O	20-50	0.1	0.02 (0.18)	3.5×10^{-6}

The muon depth-intensity curve (underground data): curves are calculated by Bugaev et al., 1998




1987A
+4
+6
+8
+10
+12
mv
McNaught
Shelton
Jones
Discovery
Jones
Mont Blanc
Kamioka,
IMB,
Baksan
Sk – 69°202
S W
(У В)
Radio (21см)
?
Shelton
0h
2h52m
7h36m
9h22m
15h54m
Feb24
Feb25
UT

February 23, 1987



The detector responses to the standard stellar collapse in the Large Magellanic Cloud

Detector	$K_{e}\ (1)$	$K_{e^-}\ (2a)+(2b)$	$K_{e^-}\ (2b)$
LSD	1.5	0.043	0.024
BUST	2	0.052	0.036
KII	17	0.53	0.36
IMB	6	0.4	0.35

$$\Phi_{\tilde{\nu}}(s^{-1}MeV^{-1}) \sim \frac{\varepsilon^2}{1+\varepsilon^2} e^{-\alpha\varepsilon^2} \quad (\varepsilon = \frac{E_{\tilde{\nu}}}{kT}) \qquad if \ \ kT \sim 2MeV$$

kT, MeV	α	$W_{\tilde{\nu}_e}\cdot 10^{54}$, эрг	k_i			
			LSD	BUST	KII	IMB
1.7	0.1	2.1±1.0	5	0.2	5±2.5	0
2.1	0.1	1.8±0.8	5	0.5	12±6	0

The total energy of neutrino radiation from SN1987A is more than an order of magnitude higher than the binding energy of neutron star with a baryon mass of about $2M_{\odot}$

$$E_{tot} = 6W_{\tilde{\nu}_e} \approx (1 \div 2)\cdot 10^{55}\, erg$$

Spherically symmetrical model

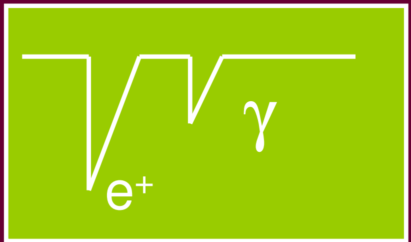
$\tilde{\nu}_e -$ detection

LSD - 5

KII - 50 (4?)

LSD event is not similar to $\tilde{\nu}p$ -detection

$\hookrightarrow e^+ + n$



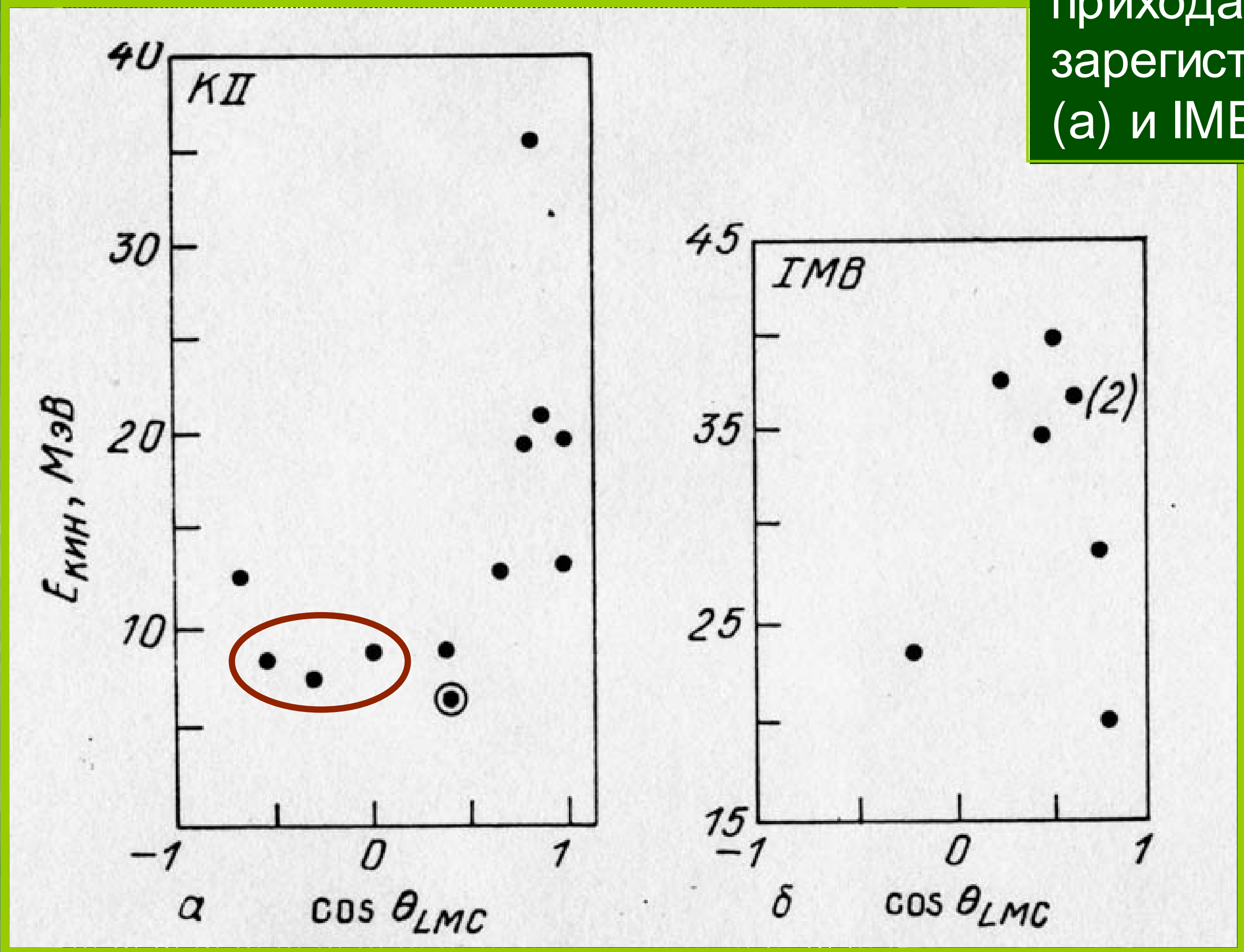
$n + p \rightarrow d + \gamma \quad \tau \sim 180\mu s$

Only 1 trigger has small pulse with $\Delta t = 278$ μsec

1. 2 years of observations N (≥5 pulses, deltaT ≤7s) = 0
2. Coincidence with SN < 1 per 1000 years
3. Distribution of pulses is uniform
4. Noises in the low energy channel (E>0.5 MeV) are absent
5. Counting rate of high energy pulses (E>25 MeV) is normal

The LSD event is not due to fluctuations.

Связь между энергией E и углом прихода для частиц зарегистрированных детекторами KII (а) и IMB (б)



Dadykin V.L., Zatsepin G.T., R.O.G., 1989, UFN

Correspondence between energy E and angle to SN1987A for pulses detected by KII and IMB

The possible solution is :

A rotating collapsar

The short review of the rotational mechanism:

On the threshold of gravitational collapse the Fe-O-C stellar core

↓

M_t – total mass, I_0 – total angular momentum

are conserved

during the collapse of the core into a rotating collapsar

The collapsar with the high probability falls into the region of the dynamical instability.

The criterion:

$$\beta = \frac{\varepsilon_{rot}}{|\varepsilon_{grav}|} \geq 0.27$$

Total rotational energy

Total gravitational energy

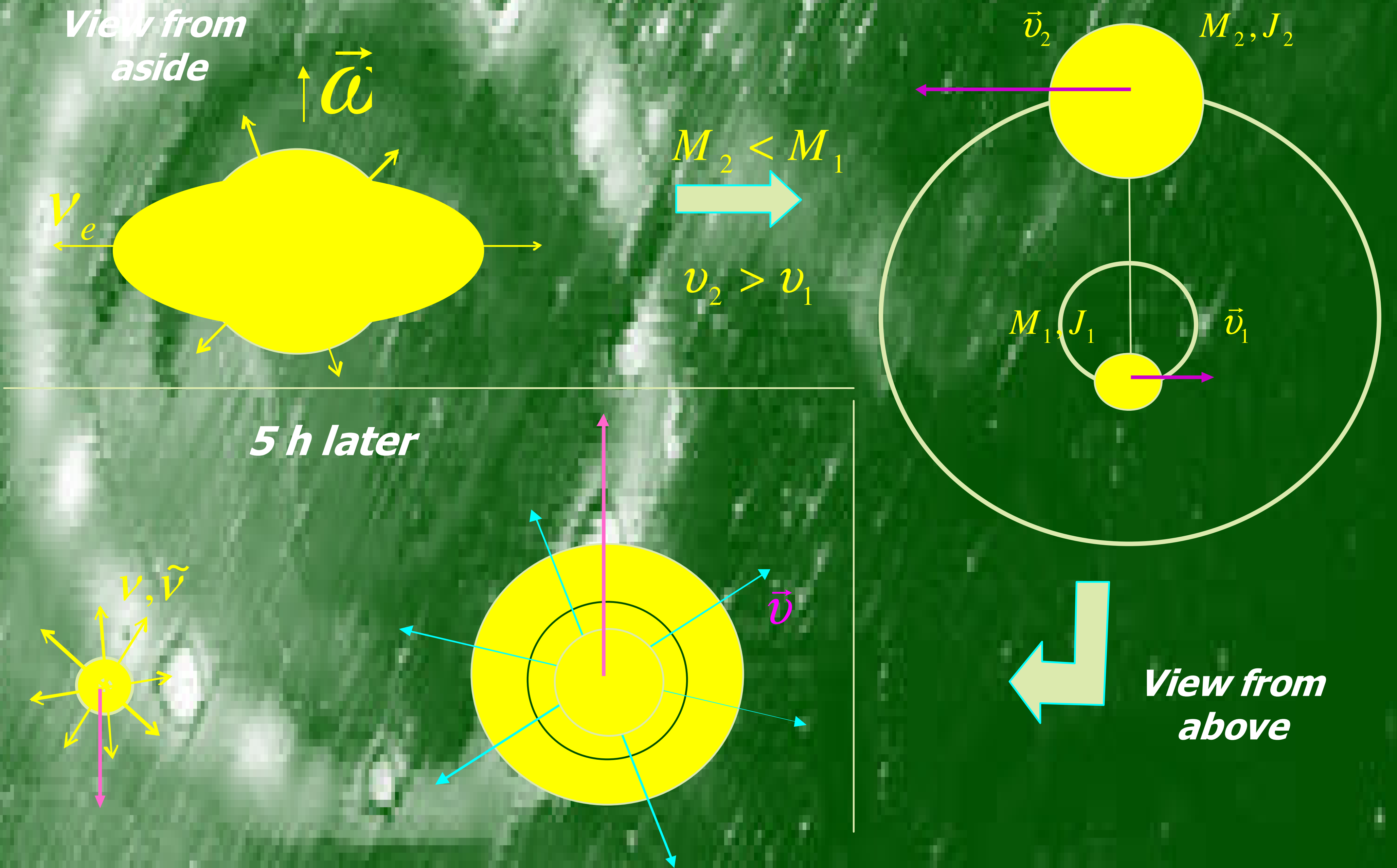
During the collapse ε_{rot} increases greatly compared to $|\varepsilon_{grav}|$, which is also an increasing quantity

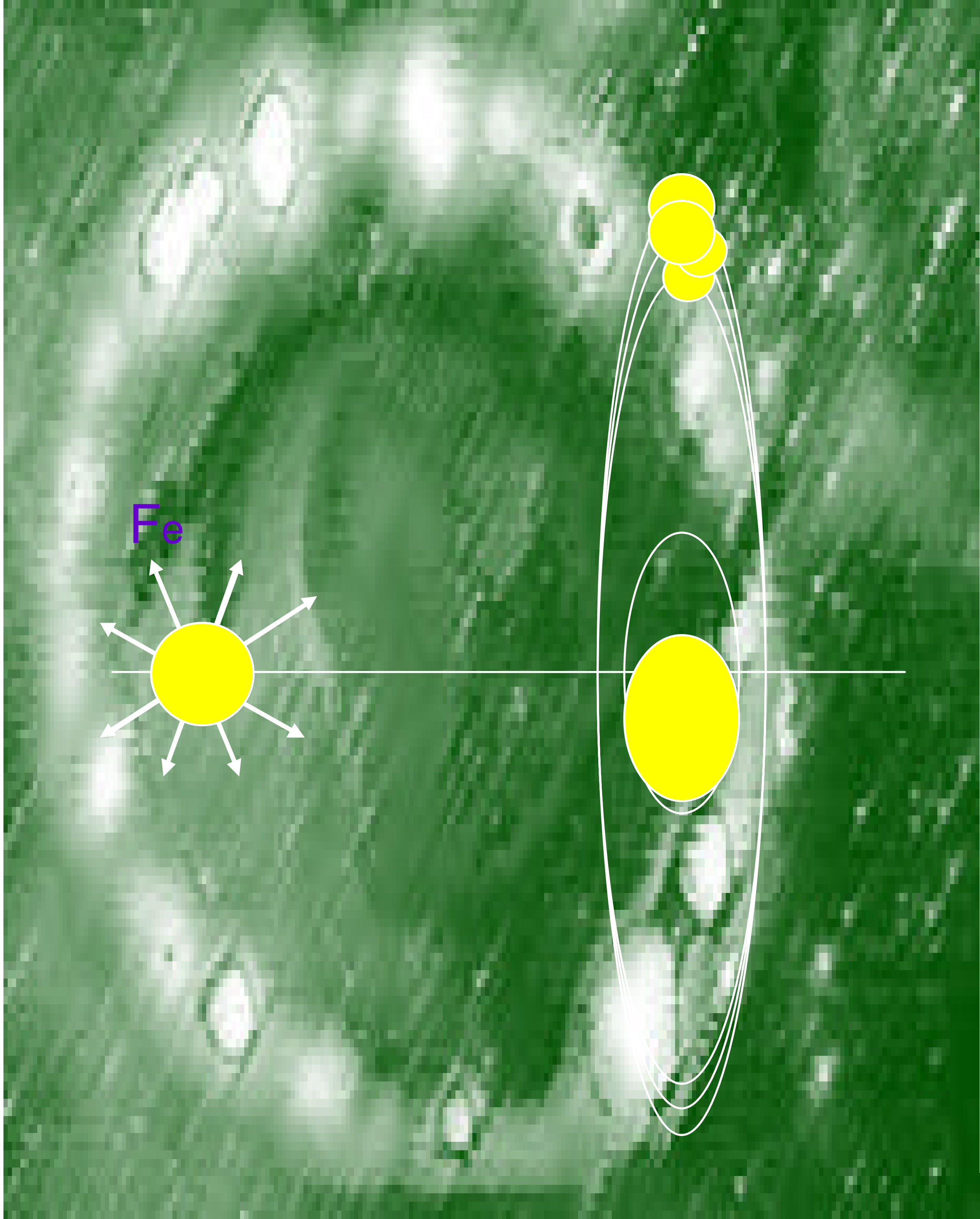
This instability grows with the characteristic hydrodynamic time and leads to the breakup of the collapsar into pieces.

A rotating collapsar

The Two-Stage Gravitational Collapse Model

[Imshennik V.S., Space Sci Rev, **74**, 325-334 (1995)]





$$J_{Fe}(E>1\ GeV) \sim 10\% J_{Fe}^{tot}$$

$$(E>10\ GeV) \sim 3\% J_{Fe}^{tot}$$

$$J_{Fe}(E) \sim \frac{1}{\sqrt{E}}$$

Fe + Fe
Fe + p
Fe + n

$$\pi^{+} \to \mu^{+} + \nu_{\mu}(\tilde{\nu}_{\mu})$$

$$\mu^{+} \to e^{+} + \nu_{e} + \tilde{\nu}_{\mu}$$

$$\mu^{-} + Fe^{56} \to \nu_{\mu} + Mn^{56}(Mn^{55}) + \ldots$$

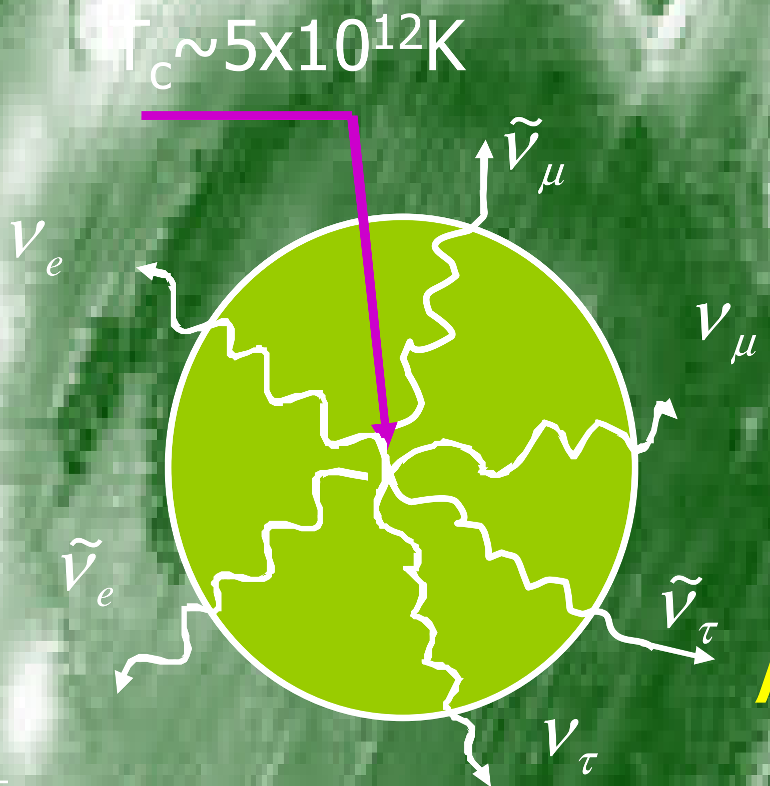
The rotation effects make it possible:

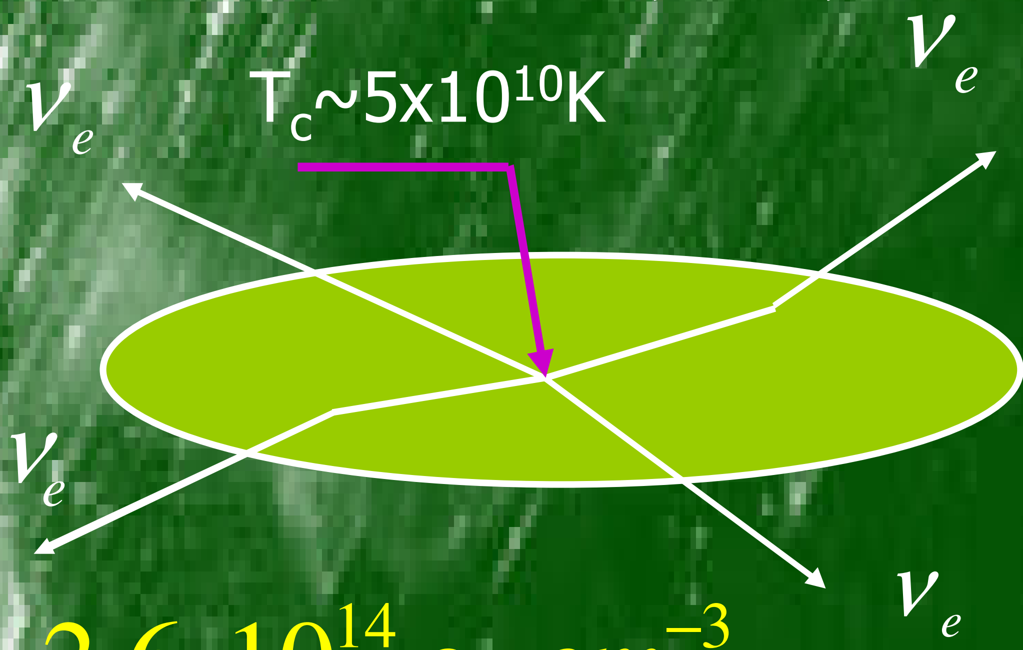
1. To resolve the problem of the transformation of collapse into an explosion for high-mass and collapsing supernovae (all types of SN, except the type Ia – thermonuclear SN)

2. To resolve the problem of two neutrino signals from SN 1987A, separated by a time interval of 4.7 h.

The difference of neutrino emission in the standard model and in the model of rotating collapsar.

Imshennik V.S., R.O.G., 2004





$$\rho \sim 2.6 \cdot 10^{14}\, g \cdot cm^{-3}$$

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

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

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

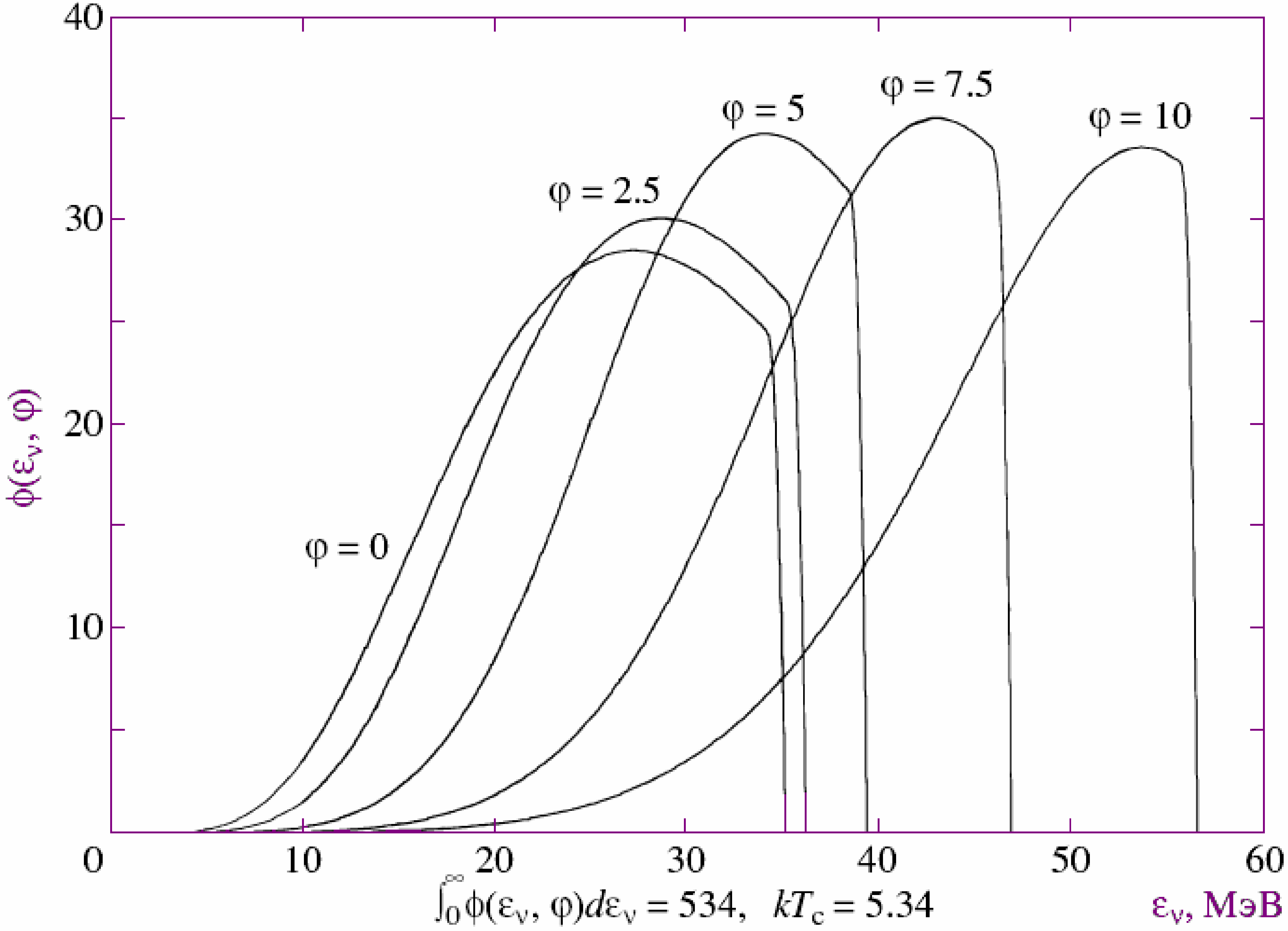
$$\varepsilon_{\nu, \tilde{\nu}} = 5.3 \cdot 10^{53} erg$$

The main reaction:

$$p + e^- \rightarrow n + \nu_e$$

$$\overline{E}_\nu = (30 - 55) MeV$$

$$\varepsilon_{\nu_e, \tilde{\nu}_e} \approx \varepsilon_{\nu_e} = 8.9 \cdot 10^{52} erg$$

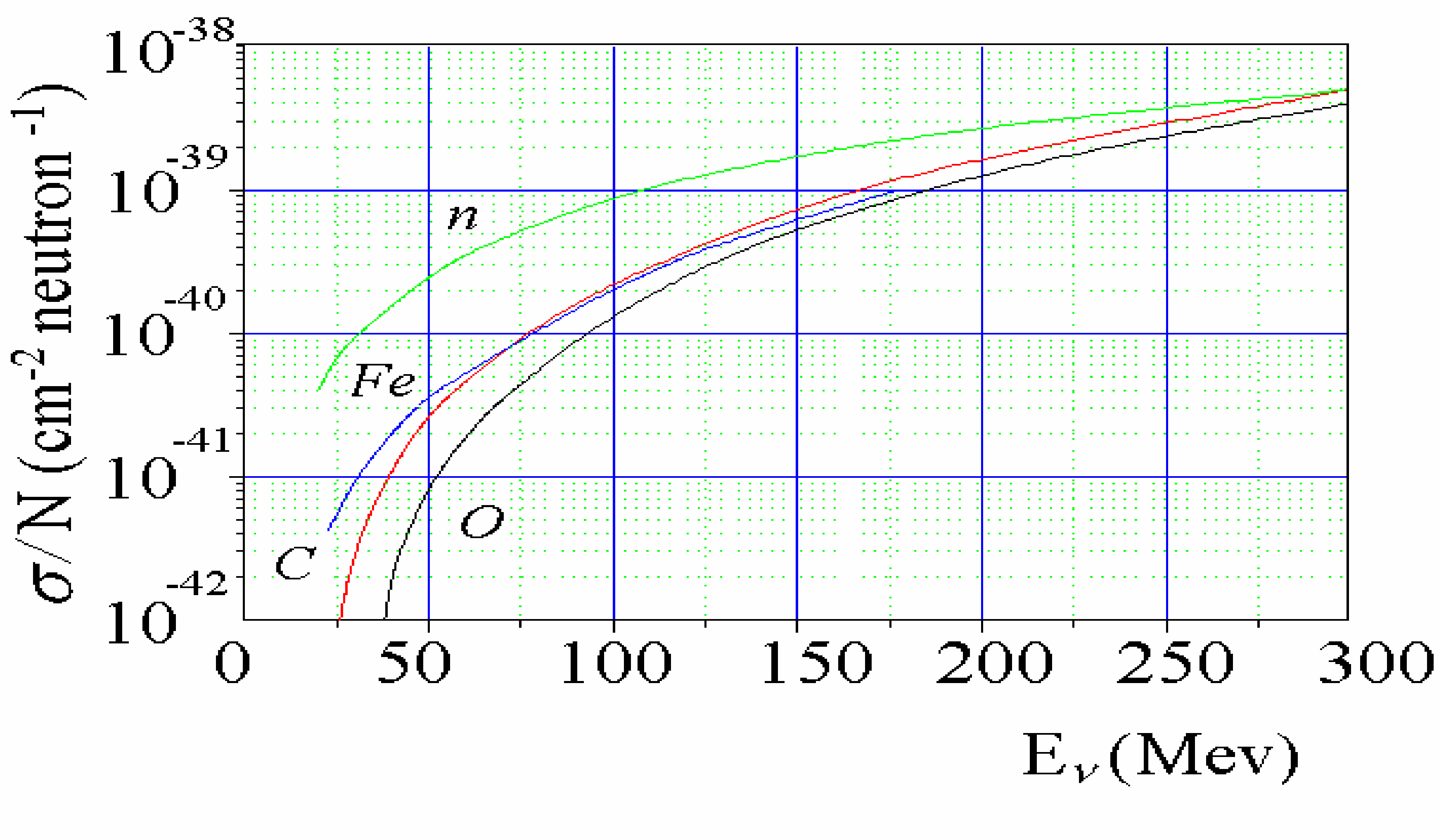


40
30
20
10
0
10
20
30
40
50
60
φ = 0
φ = 2.5
φ = 5
φ = 7.5
φ = 10
ϕ(εν, φ)
εν, МэВ
$\int_0^\infty \phi(\varepsilon_\nu, \varphi) d\varepsilon_\nu = 534, \quad kT_c = 5.34$

Let us consider how the various detectors operated during the explosion of SN1987A could record the neutrino signals in terms of the model of a rotating collapsar, which reduces to the following:

1. Two neutrino bursts separated by a time t_{grav}~5 h must exist.
2. The neutrino flux during the first burst consists of electron neutrino with a total energy of 8.9×10^{52} erg: the neutrino energy spectrum is hard and asymmetric with mean energies in the range of 25-50 MeV; the duration of the neutrino radiation is t ~ 2.4 - 6 s.
3. The second neutrino burst corresponds to the theory of standard collapse.

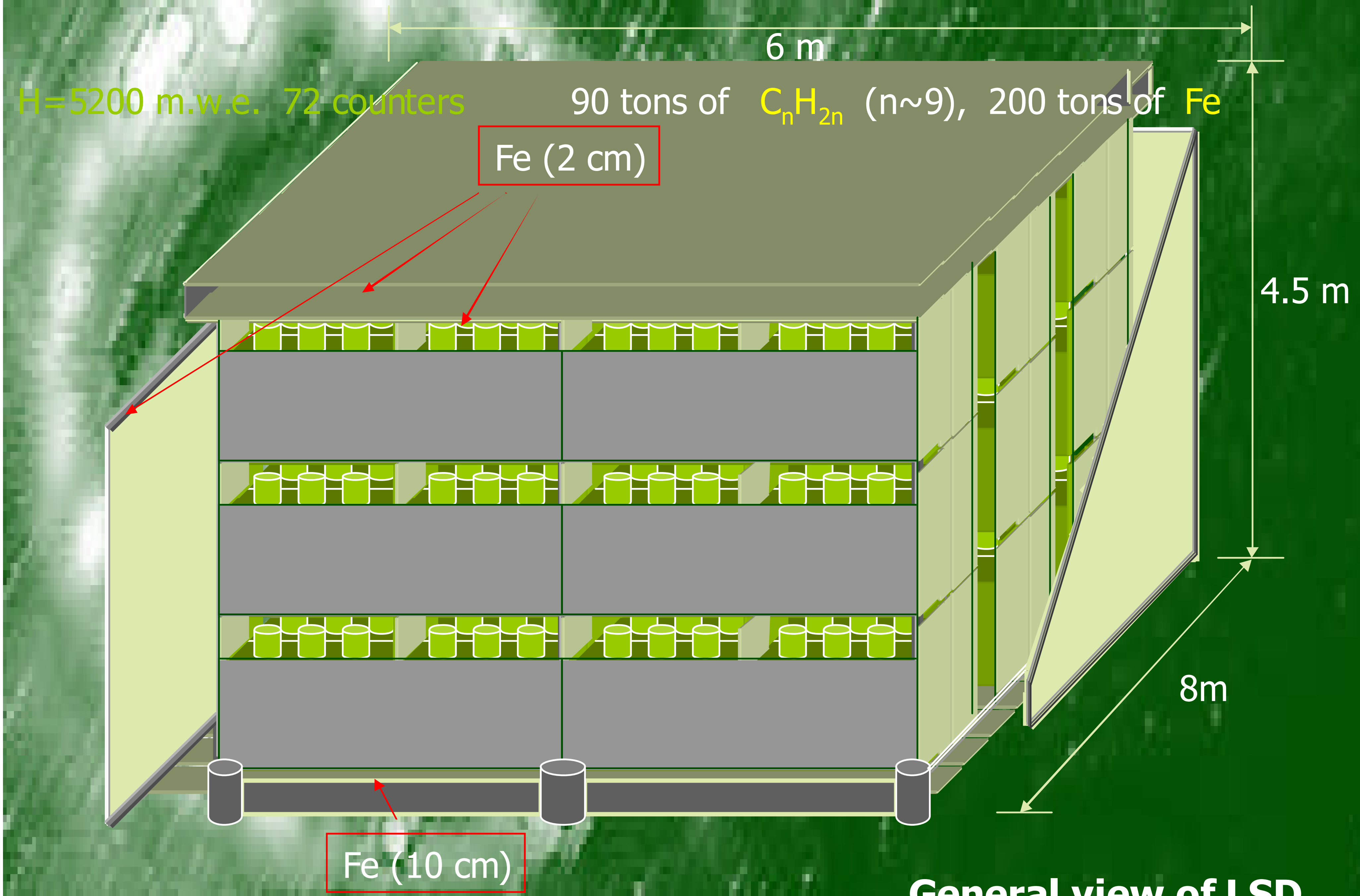
Bugaev E.V., Bisnovaty-Kogan G.S. et al., 1979



The comparison of the total reduced cross-sections with νn cross-section on a free neutron for the reaction

$$\nu_e + (A,Z) \rightarrow e^- + (A,Z+1)^*$$

Liquid Scintillator Detector (LSD)



General view of LSD

Detector	Energy threshold	Estimated number of $\nu_e A$ interaction				Estimated Effect $N_2 \cdot \eta$	Exp.
		N_1	N_2	N_3	N_4		
LSD	5 – 7	3.2	5.7	3.5	4.9	3.2	5
KII	7 – 14	0.9	3.1	1.2	2.5	2.7	2-4*
BUST	10	2.8	5.2			~1	1**

$$E_{\nu_e} = 30 MeV \ (N_1) \qquad E_{\nu_e} = 40 MeV \ (N_2)$$

$$f\left(E_{\nu_e}\right) \ with \ \varphi = 5 \ (N_3)$$

$$f\left(E_{\nu_e}\right) \ with \ \varphi = 7.5 \ (N_4)$$

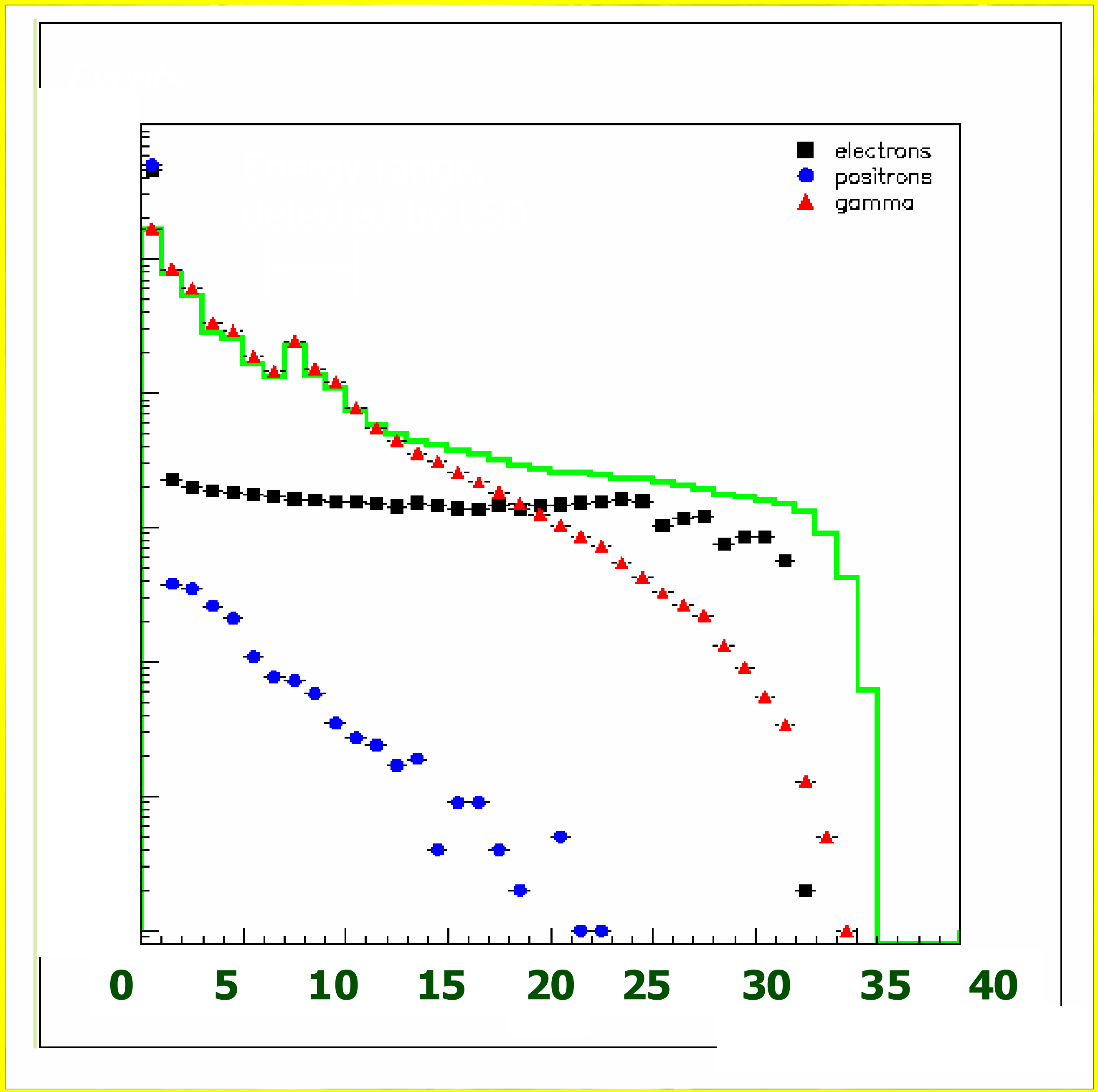
$$\varphi = \frac{\mu_e}{kT}$$

$$kT_c = 5.34 \ MeV$$

$$\rho = 2.6 \cdot 10^{14} \ g/cm^3$$

* De Rujula, 1987

** Alexeyev, 1987



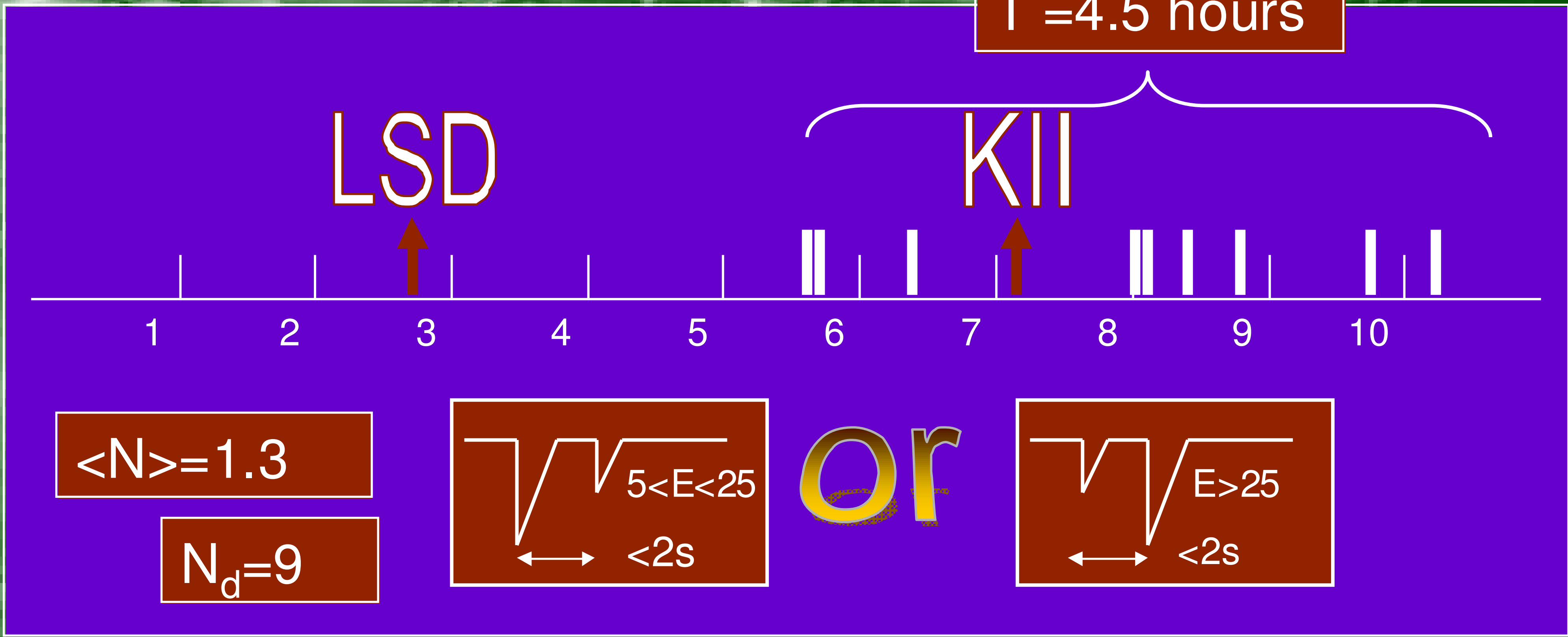
Energy spectrum of the particles, coming from 2,8 cm iron plate

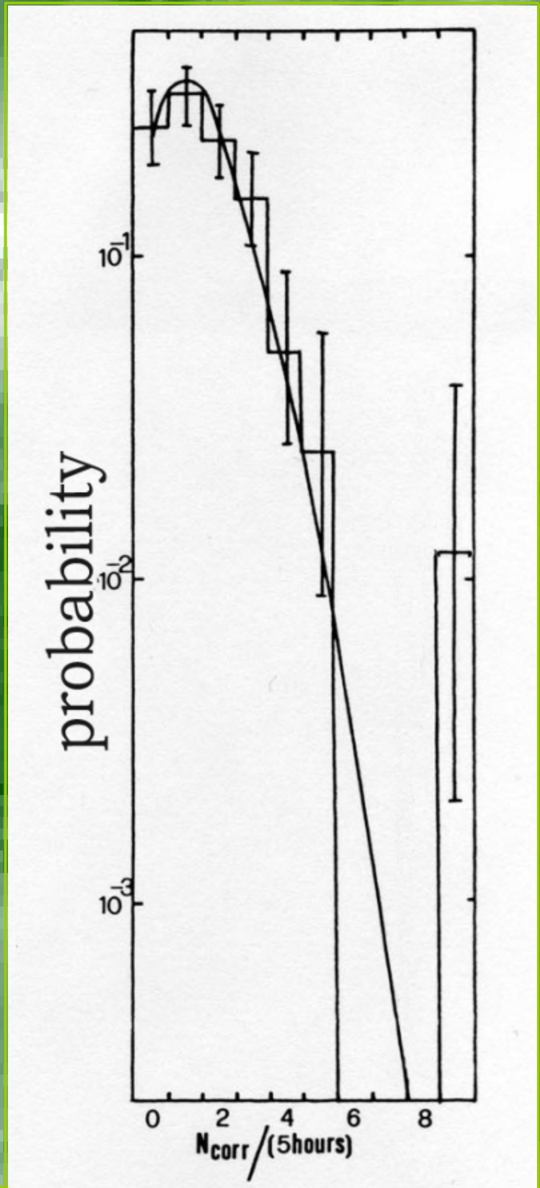
(Geant4 calculations; histogram – total energy deposit)

V. Boyarkin, 2004

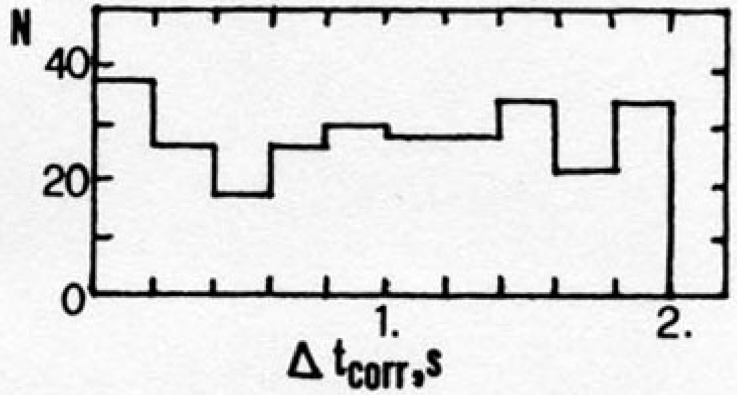
KII

№	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

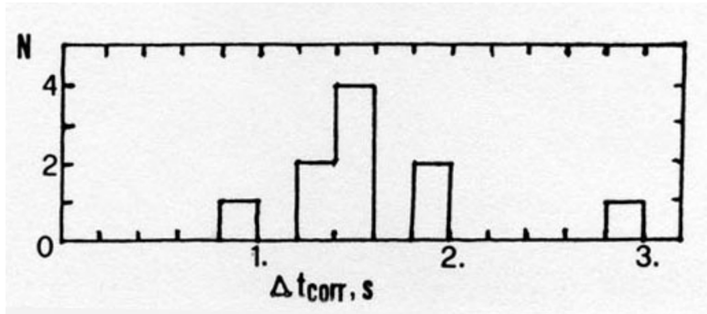




The probability distribution of the counting rate of pairs of correlated pulses per 5 hours and the poissonian fit to this distribution; $<n_{corr}>=1.46/(5$ hours), $\Delta T=2$ s



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

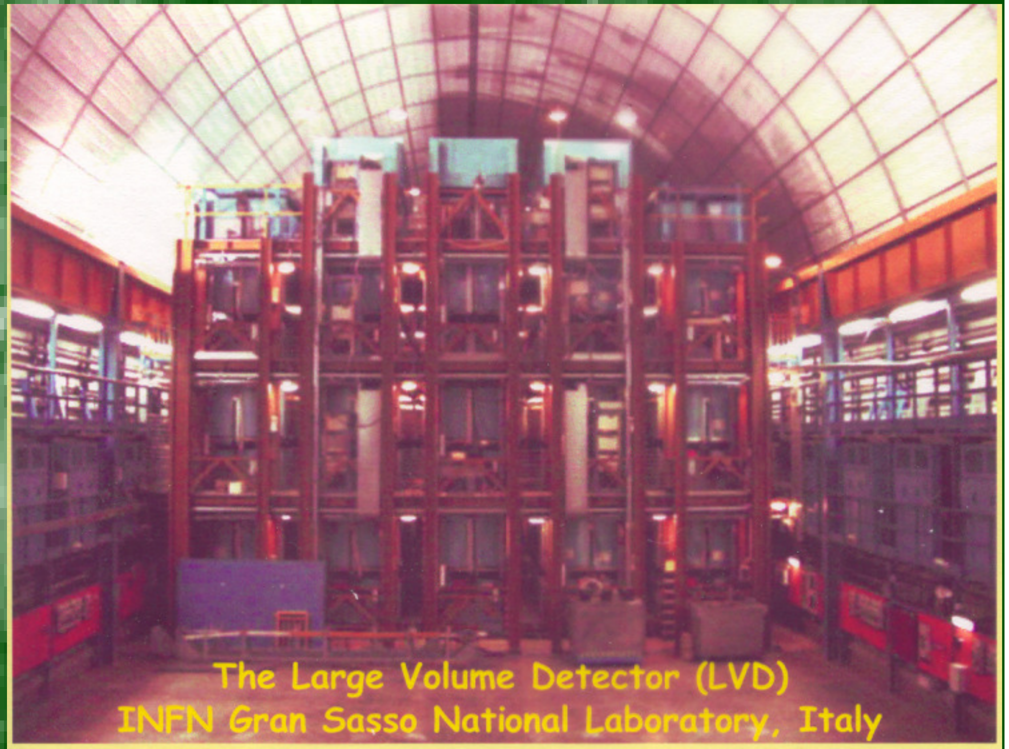
9 pairs ($\Delta t=2$ s)

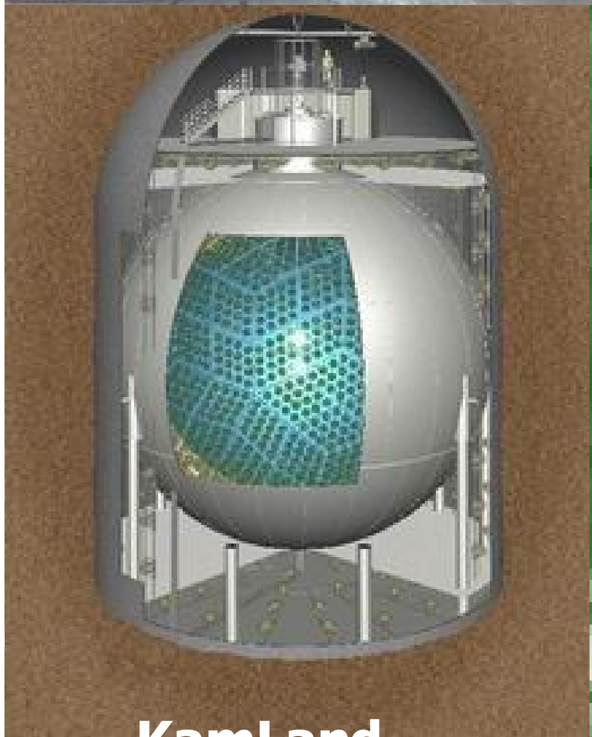
10:13UT on February 23, 1987 .

NEUTRINO DETECTORS

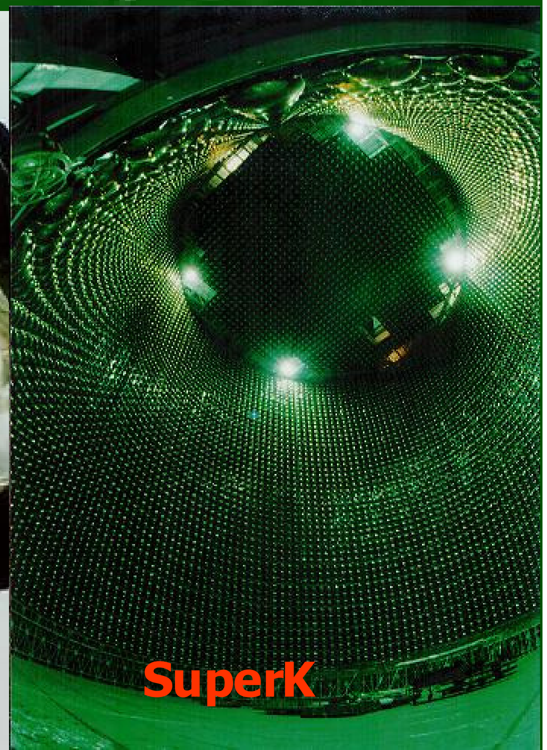
SNO

LVD





KamLand



C_nH_{2n} H_2O

Reactions for scintillation and Cherenkov counters

$\tilde{\nu}_e + p \to e^+ + n$	$\sigma_{\tilde{\nu}_e p} \sim 9.3 E_{e^+}^2 \cdot 10^{-44}\ cm^2$	$E_{e^+} >> 0.5 MэB$ $E_{e^+} = E_{\tilde{\nu}} - 1.3\ MэB$
$\nu_e + e^- \to \nu_e + e^-$ $\nu_i + e^- \to \nu_i + e^-$ $\tilde{\nu}_i + e^- \to \tilde{\nu}_i + e^-$	$\sigma_{\nu_e e^-} \sim 9.4 E_{\nu_e} \cdot 10^{-45}\ cm^2$ $\sigma_{\nu_i e^-} \sim 1.6 E_{\nu_i} \cdot 10^{-45}\ cm^2$ $\sigma_{\tilde{\nu}_e e^-} \sim 1.3 E_{\tilde{\nu}_i} \cdot 10^{-45}\ cm^2$	
$\nu + {}^{12}C \to {}^{12}C^* + \nu - 15.1\ MeV$ $\quad\hookrightarrow {}^{12}C + \gamma\ (15.1\ MeV)$	$\bar{\sigma}_{\nu_e} (\bar{E}_{\nu_e} = 10 MeV) = 0.066 \cdot 10^{-42}\ cm^2$ $\bar{\sigma}_{\mu,e} (\bar{E}_{\nu_\mu} = 20 MeV) = 1.23 \cdot 10^{-42}\ cm^2$	
$\nu_e + {}^{12}C \to {}^{12}N + e^-$ $\quad\hookrightarrow {}^{12}C + e^+ + \nu_e$	$E_{thr} = 17.34\ MeV$	$\tau = 15.9\ ms$
$\tilde{\nu}_e + {}^{12}C \to {}^{12}B + e^+$ $\quad\hookrightarrow {}^{12}C + e^- + \tilde{\nu}_e$	$E_{thr} = 14.4\ MeV$	$\tau = 29.3\ ms$

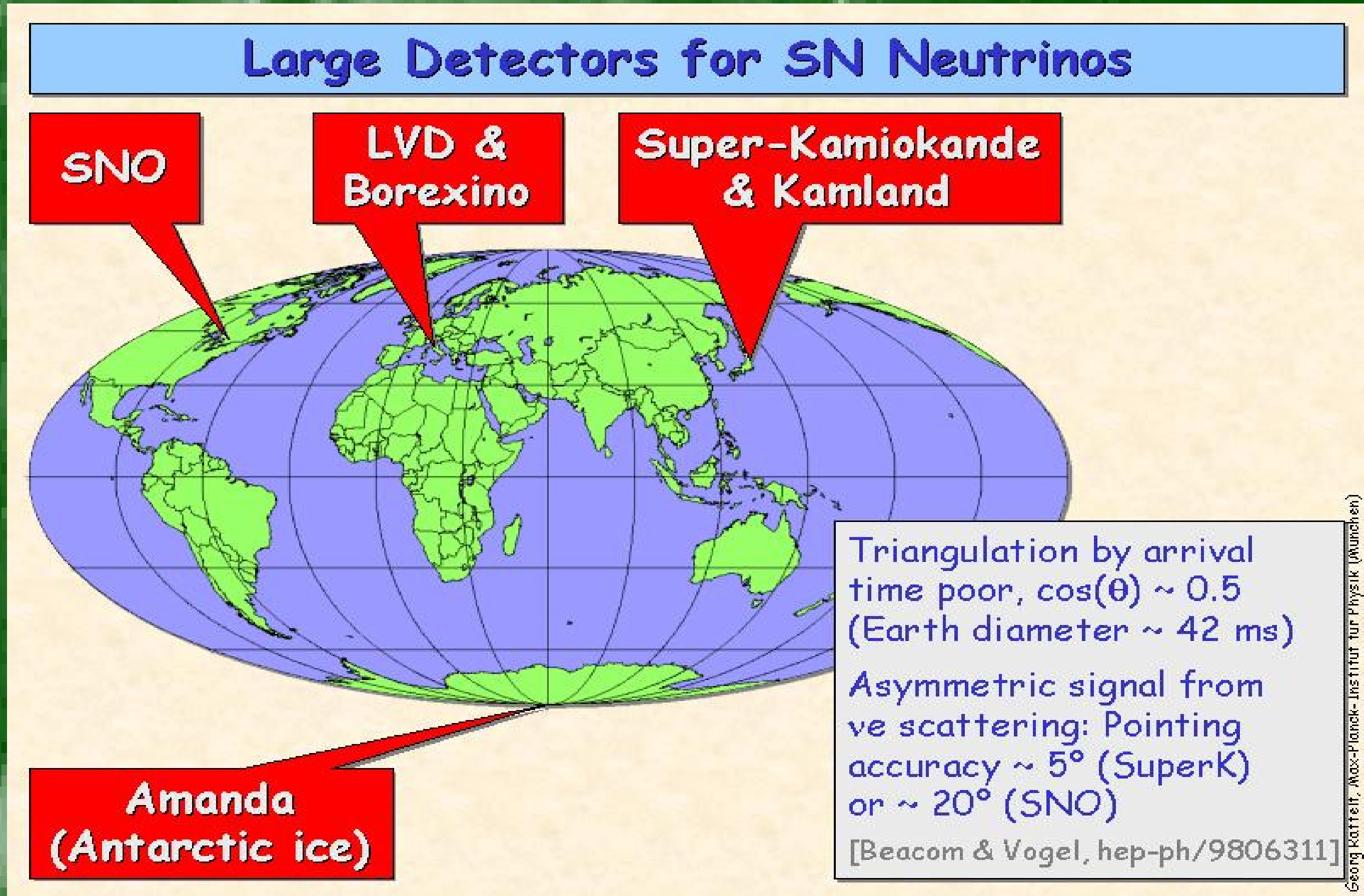
Detector	Depth m.w.e	Mass, ktons	Threshold, MeV	Efficiency η_{e^+}	Efficiency η_n	Efficiency η_γ	Number of events $\tilde{\nu}_e p$, $\tilde{\nu}_e D+\nu_e D$	Number of events $\nu_e A$	Number of events $\nu_e C$	Background s^{-1}
Arteomovsk **ASD** Russia	570	0.1 C_nH_{2n}	5	0.97	0.8	0.85	57		19* 9**	0.16
Baksan **BUST** Russia	850	0.13 (0.2) C_nH_{2n}	10	0.6	-	0.2	45 (67)		5*(8) 3**(4)	0.013 (0.033)
KamLAND USA Japan	2700	1. C_nH_{2n}	~ 4				500		180* 80**	
Gran Sasso **LVD** Italy,Russia	3300	0.95 Fe 1. C_nH_{2n}	4 – 6	0.9	0.6	0.55	500	250* 100**	110* 50**	< 0.1
Kamioka **Super-K** Japan,USA	2700	22.5 H_2O	5.5	0.9	-	-	9400	650* <160**		
SNO Canada	6000	1 D_2O	5				700	600* 350**		

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

The search for neutrino bursts from collapsing stars was started ~ 29.5 years ago.

Upper limit of collapse rate in Galaxy is less than 12 years at 90% confidence level

Collapse (Arteomovsk, 1977 - now),
BUST (1978 - now),
LSD (1984 - 1999),
LVD (1991 - now).

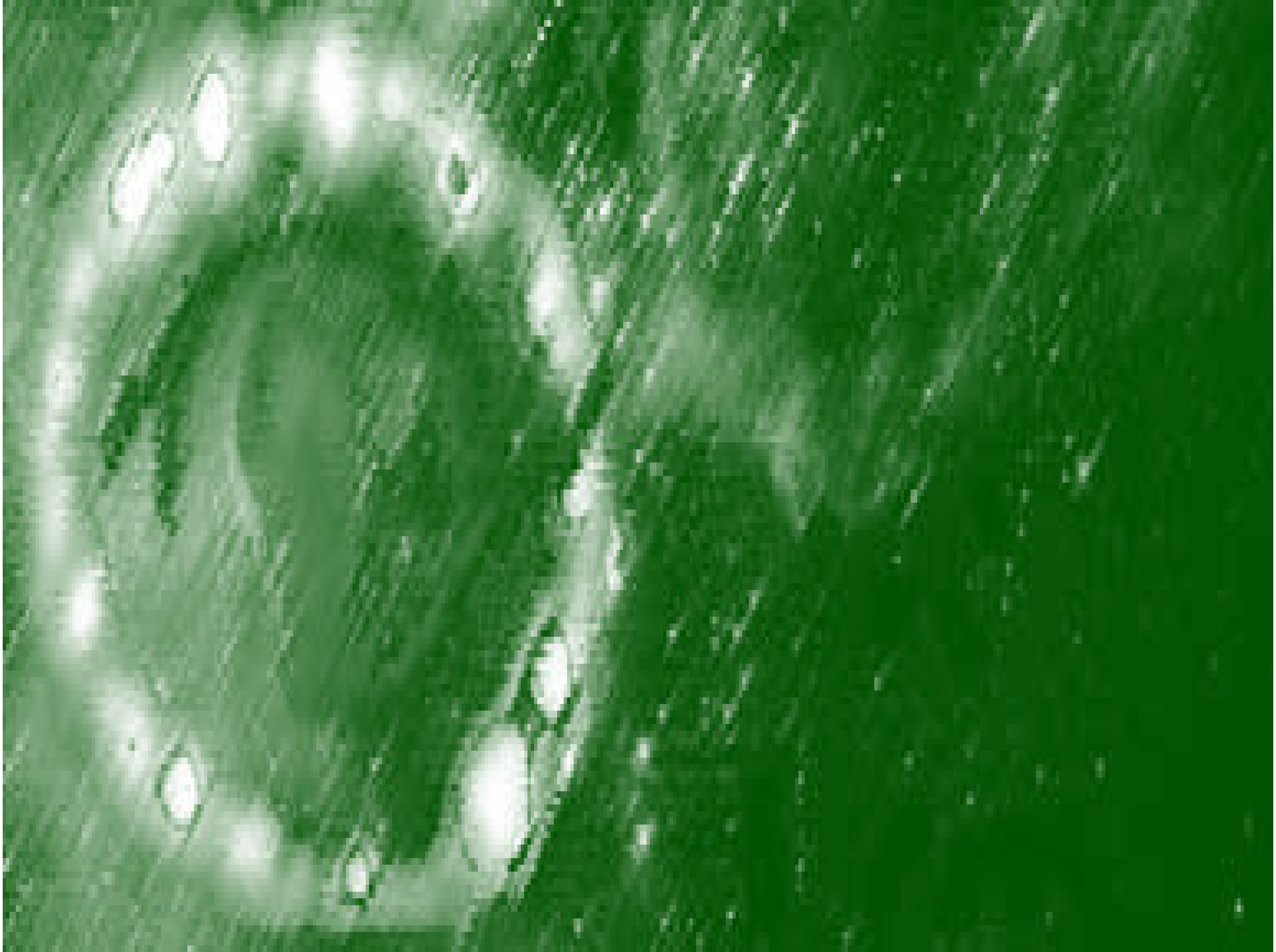


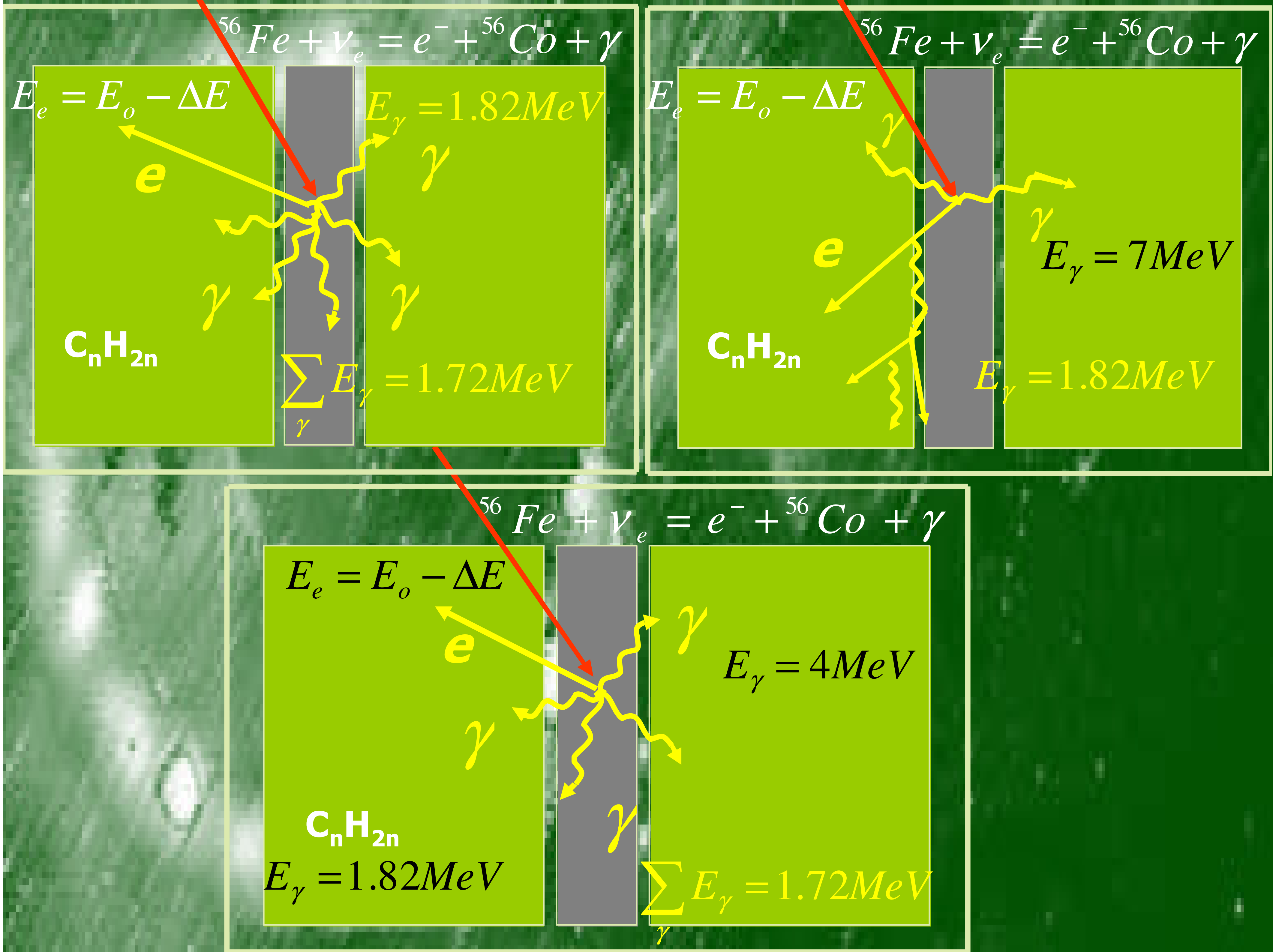

We are waiting for
SN's . . . .

Cari amici!

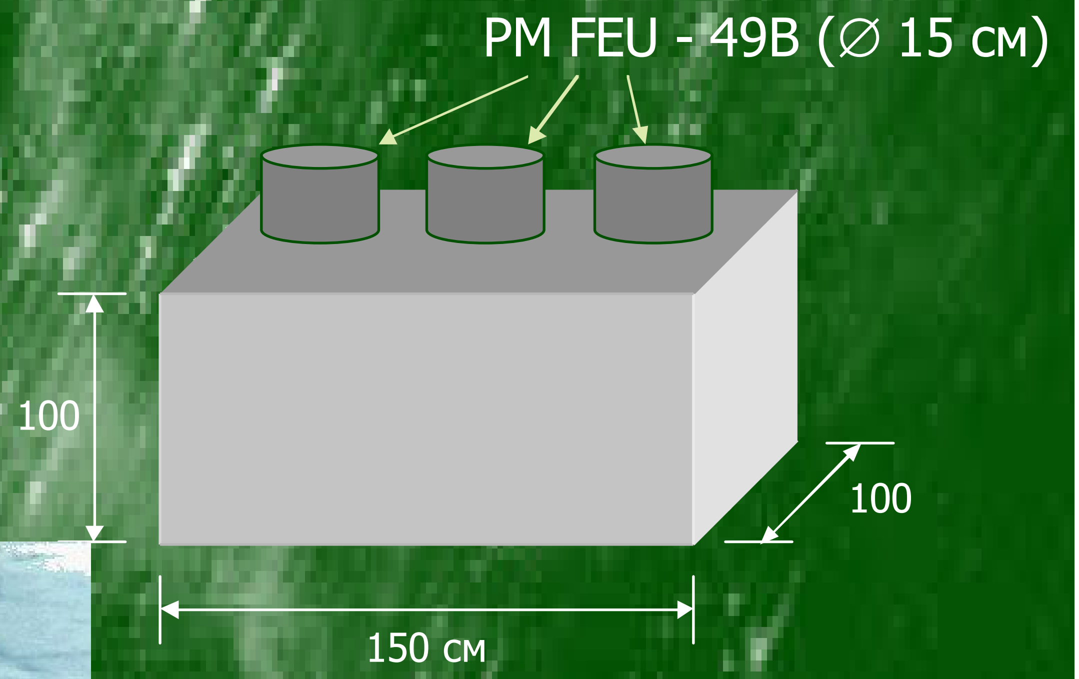
Grazie mille per la nostra collaborazione perfetta e la nostra amicizia di piu di 30 anni. ☺

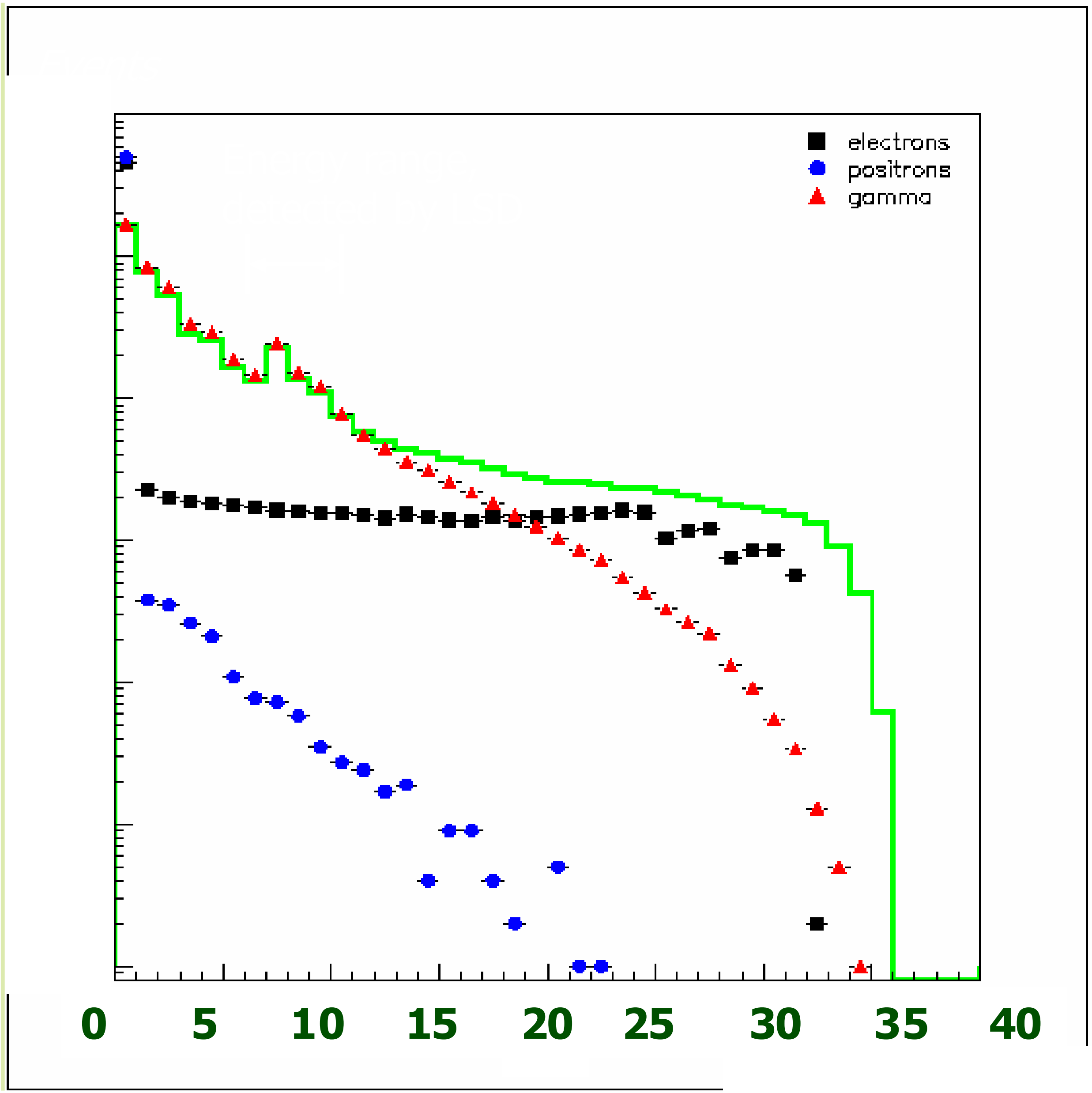
Спасибо





$^{56}Fe + \nu_e = e^- + ^{56}Co + \gamma$
$E_e = E_o - \Delta E$
$E_\gamma = 1.82 MeV$
e
γ
C_nH_{2n}
$\sum_\gamma E_\gamma = 1.72 MeV$
$^{56}Fe + \nu_e = e^- + ^{56}Co + \gamma$
$E_e = E_o - \Delta E$
γ
e
$E_\gamma = 7 MeV$
C_nH_{2n}
$E_\gamma = 1.82 MeV$
$^{56}Fe + \nu_e = e^- + ^{56}Co + \gamma$
$E_e = E_o - \Delta E$
e
γ
$E_\gamma = 4 MeV$
C_nH_{2n}
$E_\gamma = 1.82 MeV$
$\sum_\gamma E_\gamma = 1.72 MeV$


PM FEU - 49B (∅ 15 см)
100
100
150 см



Energy spectrum of the particles, coming from 2,8 cm iron plate

(Geant4 calculations; histogram – total energy deposit)

Yu.V. Gaponov, S.V. Semenov

1^+ GT	10,589
1^+ GT	7,589
1^+ GT	4,589
0^+ IAS	3,589
1^+	1,72
4^+	

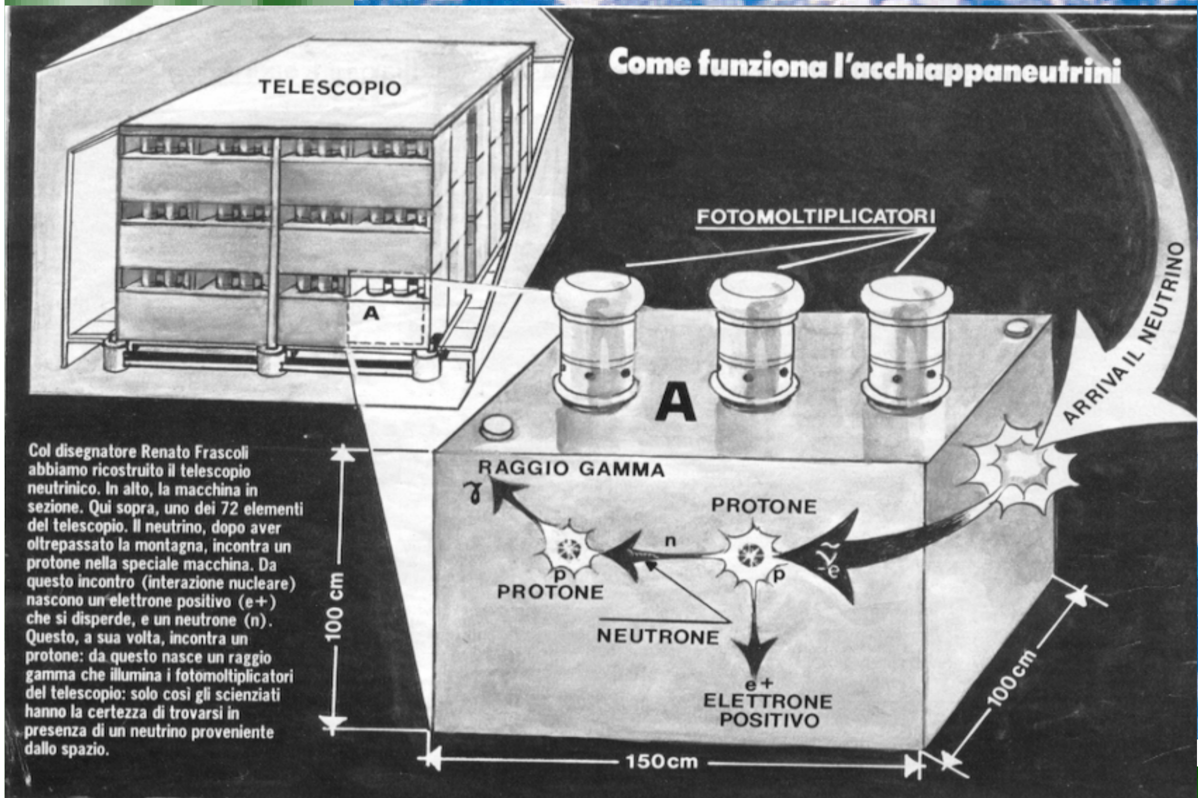
$^{56}_{27}Co$

$$\nu_e + {}^{56}_{26}Fe_{0^+} \rightarrow {}^{56}_{27}Co + e^-$$

$$E\left({}^{56}_{27}Co\right) - E\left({}^{56}_{26}Fe\right) = 4.056\ MeV$$

$$E_\nu = 40\ MeV \qquad \sigma_{tot} = 4.24E^{-40}cm^2$$

F	$\sigma = 1.27 \cdot 10^{-40}\ cm^2$	$E_{K,e^-} = 31.84 MeV$ $E_\gamma = 1.82 MeV \quad \sum_n E_\gamma = 1.72 MeV$
GT	$\sigma = 6.41 \cdot 10^{-41}\ cm^2$	$E_{K,e^-} = 30.84\ MeV \quad E_\gamma = 1\ MeV$ $E_\gamma = 1.82\ MeV \quad \sum_n E_\gamma = 1.72\ MeV$
GT	$\sigma = 1.05 \cdot 10^{-40}\ cm^2$	$E_{K,e^-} = 27.84 MeV \quad E_\gamma = 4 MeV$ $E_\gamma = 1.82 MeV \quad \sum_n E_\gamma = 1.72 MeV$
GT	$\sigma = 1.27 \cdot 10^{-40}\ cm^2$	$E_{K,e^-} = 24.84\ MeV \quad E_\gamma = 7\ MeV$ $E_\gamma = 1.82\ MeV \quad \sum_n E_\gamma = 1.72\ MeV$



Col disegnatore Renato Frascoli abbiamo ricostruito il telescopio neutrinico. In alto, la macchina in sezione. Qui sopra, uno dei 72 elementi del telescopio. Il neutrino, dopo aver oltrepassato la montagna, incontra un protone nella speciale macchina. Da questo incontro (interazione nucleare) nascono un elettrone positivo (e+) che si disperde, e un neutrone (n). Questo, a sua volta, incontra un protone: da questo nasce un raggio gamma che illumina i fotomoltiplicatori del telescopio: solo così gli scienziati hanno la certezza di trovarsi in presenza di un neutrino proveniente dallo spazio.

Events, detected by LSD

February,23, 1987 г. (SN 1987 A)

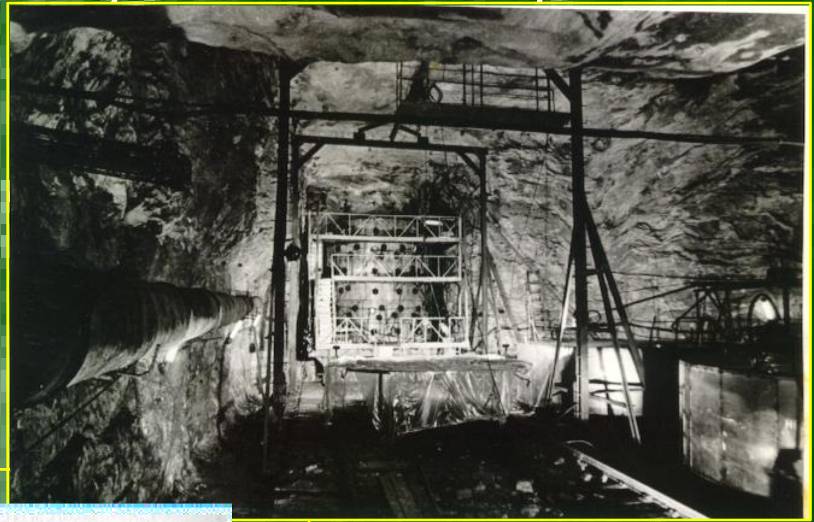
# of event	Time, UT±2ms	Energy, MeV
1	2:52:36,79	6,2 – 7
2	40,65	5,8 – 8
3	41,01	7,8 –11
4	42,70	7,0 – 7
5	43,80	6,8 – 9
1	7:36:00,54	8
2	7:36:18,88	9

1977 ***Arteomovsk Scintillation Detector*** (INR RAS) has scintillator mass of 105 t, good signature of events (the possibility to detect both particles in the reaction)

$$\bar{\nu}+p \rightarrow e^{+}+n$$

$$n+p \rightarrow d^{*}$$

$$\hookrightarrow d+\gamma \quad E_{\gamma}=2.2\ MeV$$



1978 ***Baksan Underground Scintillation Telescope*** (INR RAS) with a total mass of 330 t

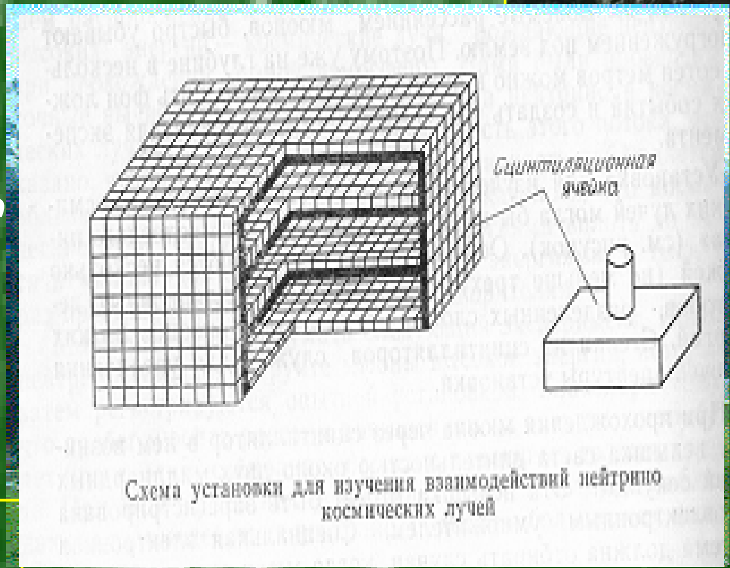


Схема установки для изучения взаимодействий нейтрино космических лучей

1984 ***LSD*** –
(Liquid Scintillation Detector, USSR – Italy), scintillator mass - 90 t, good signature of events (the possibility to detect both particles in the reaction : $\tilde{\nu}p \rightarrow ne^{+}$)

the best agreement with our data.

12. – Conclusions.

We have described some of the topics on muon physics deep underground that our group of the Mont Blanc laboratory has been working on during 20 years. The past and the present activities involve both search on the nature of elementary-particle high-energy interactions and many astrophysical topics.

The dimensions of the experiments grew up by a factor of 10 every 10 years of the Mont Blanc activities. For the next few years much more massive detectors, ~ 2000 tons of active material is forecasted to be used as a natural upgrading of the next generation of underground detectors. However, it is not possible to build such a detector in the Mt. Blanc Laboratory because of the lack of available space.

Consequently it is not fortuitous that the Gran Sasso Laboratory will be suitable for a multipurpose experiment such as that our group proposed to make; in order to extend our activities we need such a Laboratory which presents unique features including impressive large halls with easy access and basic facilities.

The LVD (Large Volume Detector) as a UNO-2 (Underground Neutrino Observatory) ([44]) has all the features to develop a multipurpose experiment combining several topics of particle physics and astrophysics with the purpose of exploring a wide range of scientific fields.

Nevertheless, the LSD or UNO-1 experiment at Mt. Blanc plays an important role in the context of the network of neutrino astronomy since the present limit to search for neutrino burst from collapsing stars is imposed

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([44]) C. Alberini, G. Bari, M. Basile, G. Cara Romeo, A. Castelvetri, L. Cifarelli, A. Contin, C. Del Papa, D. Galli, G. Iacobucci, G. C. Maccarrone, T. Massam, F. Motta, E. Nania, R. Odorico, G. Prisco, G. Rinaldi, G. Sartorelli, G. Barbagli, P. G. Pelfer, R. Casaccia, I. Laasko, A. Rindi, G. C. Susinno, L. Votano, F. Cardone, G. Di Sciascio, R. Scrimaglio, G. D'Alí, M. Aglietta, C. Castagnoli, A. Castellina, W. Fulgione, C. Morello, L. Periale, G. Trinchero, P. Vallania, S. Vernetto, G. Badino, L. Bergamasco, G. Cini, M. Dardo, P. Galeotti, G. Navarra, O. Saavedra, R. Meunier, F. Rohrbach, A. Zichichi, V. S. Berezinsky, V. Z. Dadykin, F. F. Khalchukov, P. V. Kortchaguin, V. B. Kortchaguin, E. V. Korolkova, V. A. Kudryavtsev, A. S. Malguin, M. A. Markov, V. G. Ryassny, O. G. Ryazhskaya, V. P. Talochkin, V. F. Yakushev and G. T. Zatsepin: this issue, p. 237.

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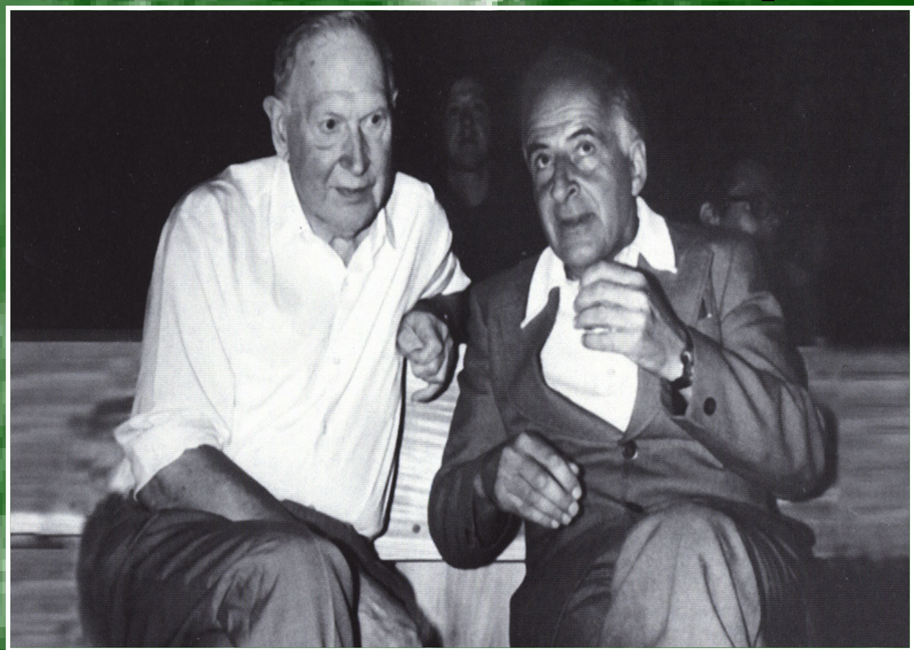
М. Марков



Б. Понтекорво