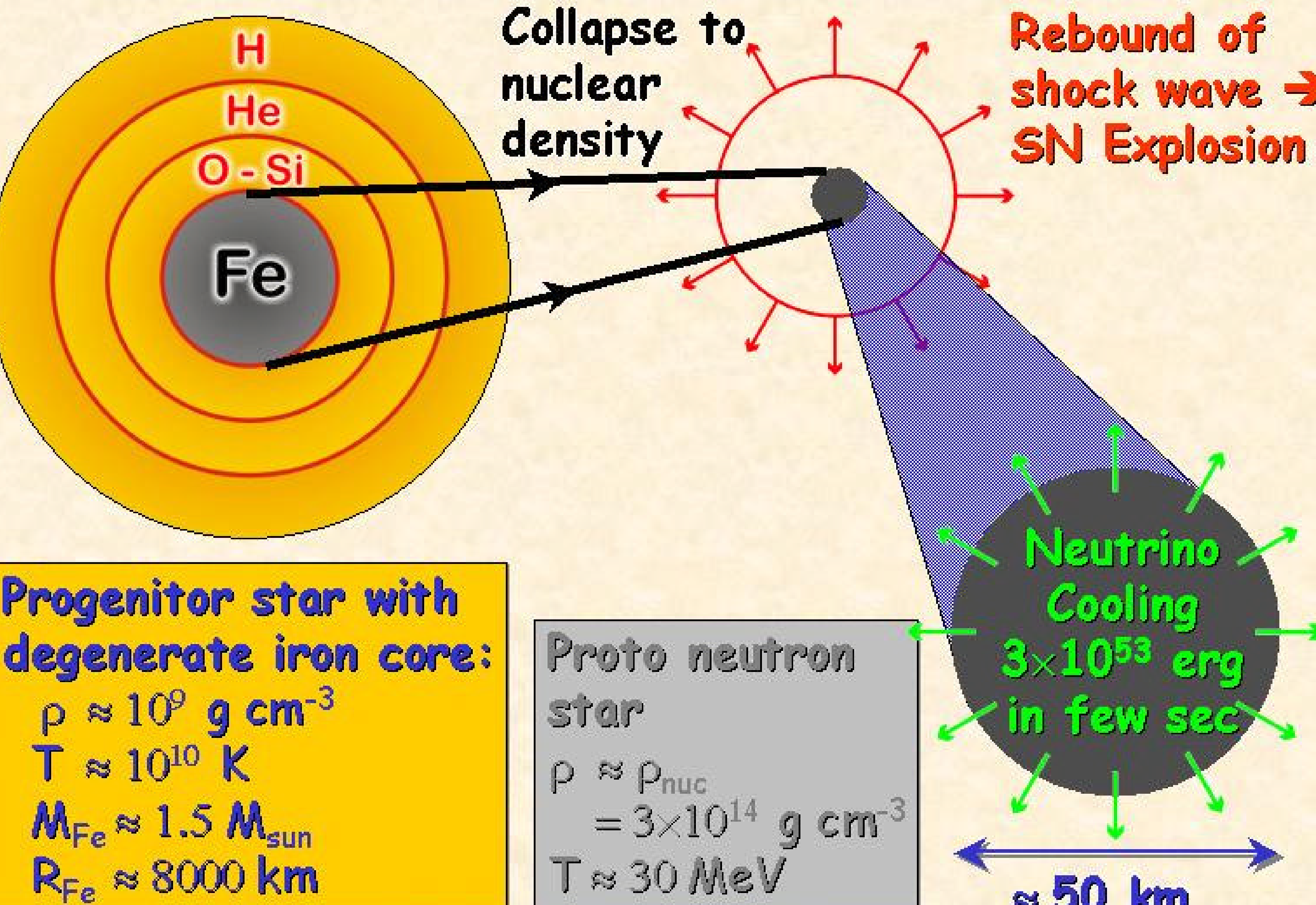
見十一日沒三年三月乙巳出東南方大中祥
年正月丁丑見南斗魁前天禧五年四月丙辰出軒
前星西北大如桃速行經軒轅大星入太微垣掩右
法犯次將歷屏星西北凡七十五日入濁沒明道
年六月乙巳出東北方近濁有芒彗至丁巳凡十
日沒至和元年五月己丑出天關東南可數寸歲
稍沒熙寧二年六月丙辰出箕度中至七月丁卯
箕乃散三年十一月丁未出天囷元祐六年十一
辛亥出參度中犯掩側星壬子犯九游星十二月
酉入奎至七年三月辛亥乃散紹興八年五月守

宋史志卷九

Stellar Collapse and Supernova Explosion



Collapse to nuclear density

Rebound of shock wave → SN Explosion

Neutrino Cooling 3×10^{53} erg in few sec

Progenitor star with degenerate iron core:

$\rho \approx 10^{9}$ g cm^{-3}

$T \approx 10^{10}$ K

$M_{Fe} \approx 1.5\ M_{sun}$

$R_{Fe} \approx 8000$ km

Proto neutron star

$\rho \approx \rho_{nuc} = 3\times10^{14}$ g cm^{-3}

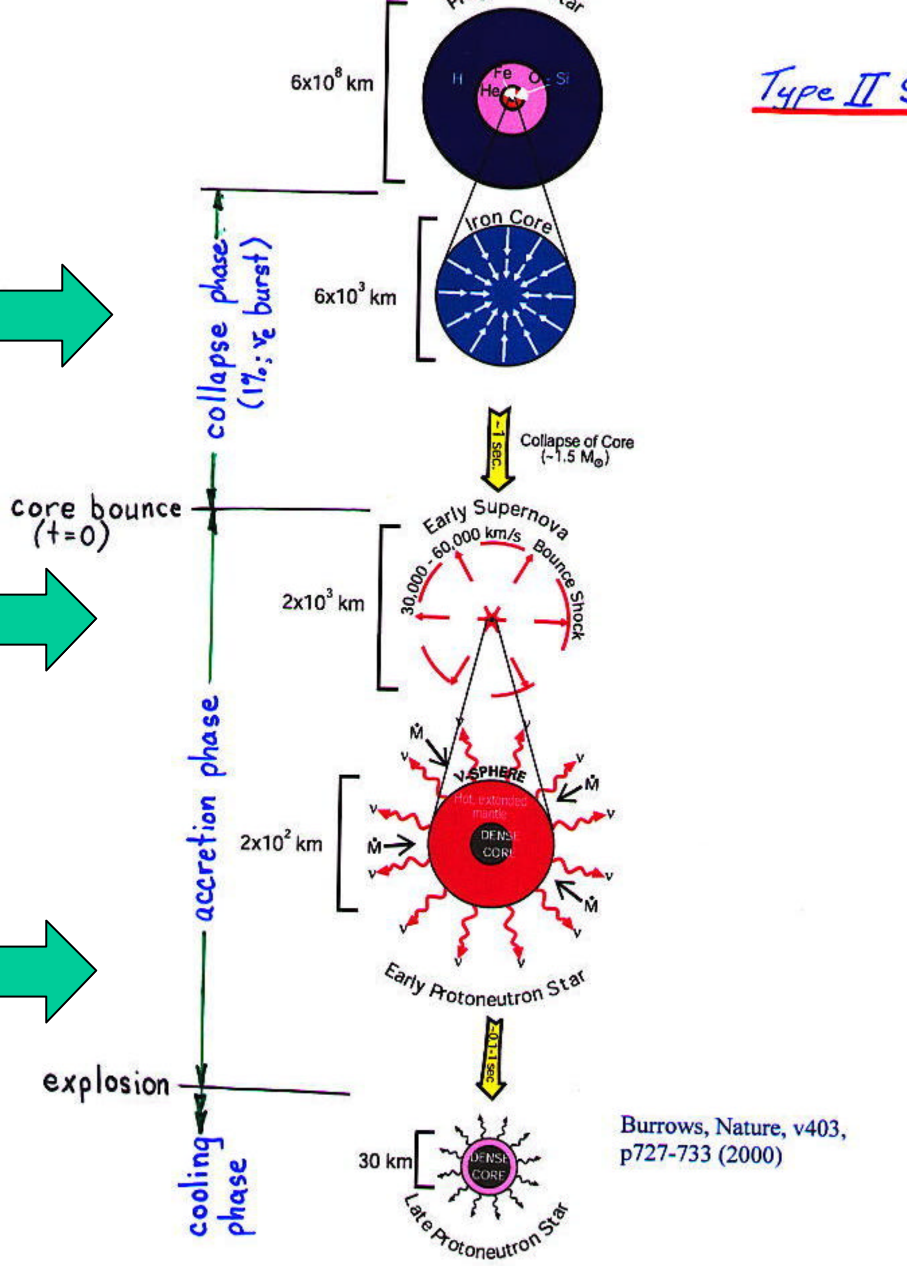
$T \approx 30$ MeV

$$M_C > M_{Ch} = 5.76\ Y_e^{\ 2}\ M_O$$

$$e^{-} + p \text{ — } n + \nu_e$$

$$\lambda_\nu = (n\sigma)^{-1}$$

$$\Delta E_B = GM^2/R_{ns} - GM^2/R_C$$



Burrows, Nature, v403, p727-733 (2000)

Classification of Supernovae

Type	Ia	Ib	Ic	II
Spectrum	No Hydrogen			Hydrogen
	Silicon	No Silicon		
		Helium	No Helium	
Physical mechanism	Nuclear explosion of low mass star	Core collapse of evolved massive star (may have lost its hydrogen or even heliu envelope during red-giant evolution)		
Light curve	Reproducible	Large Variations		
Neutrinos	Insignificant	~ 100 × Visible energy		
Compact Remnant	None	Neutron star (typically appears as pulsar) Sometimes black hole ?		
Rate/h^2SNu	0.36 ± 0.11	0.14 ± 0.07		0.71 ± 0.34
Observed	Total ~ 2000 as of today (nowadays ~200/year)			

Core Collapse Supernova Energetics

Liberated gravitational binding energy of neutron star:

$$E_b \approx 3 \times 10^{53}\ \mathrm{erg} \approx 17\%\ M_{SUN}c^2$$

$$E_b = GM^2/R_{ns} - GM^2/R_{core}$$

This shows up as

99%	Neutrinos
1%	Kinetic energy of explosion (1% of this into cosmic rays)
0.01%	Photons (outshine host galaxy)

Neutrino luminosity

$$L_\nu \approx 3\times10^{53}\ \mathrm{erg}\ /\ 3\ \mathrm{sec} \approx 3\times10^{19}\ L_{SUN}$$

While it lasts, outshines the photon luminosity of the entire visible universe!

STELLAR COLLAPSE

A stellar collapse is unavoidable when the Fe core mass exceeds the Chandrasekhar limit mass

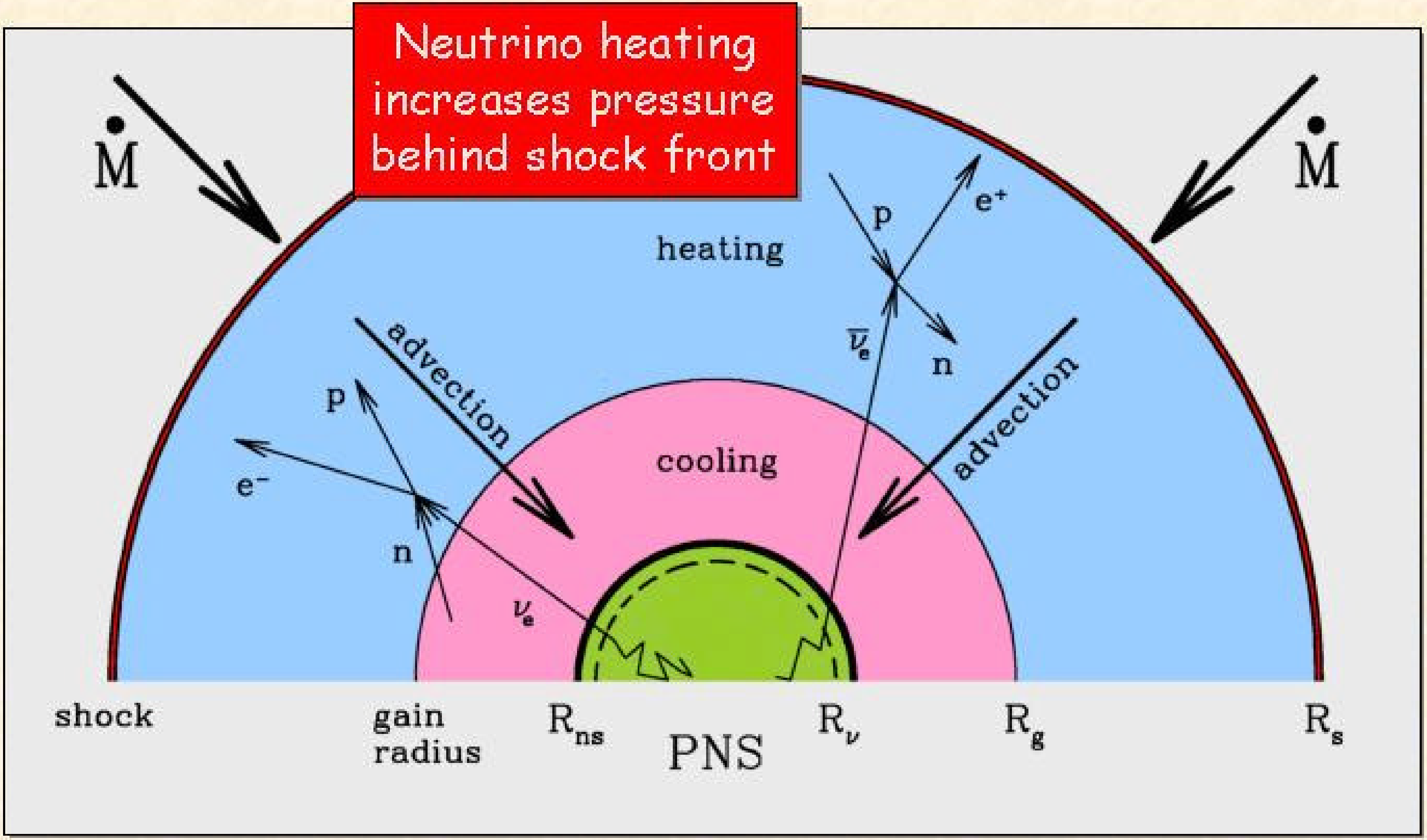
$$\mathbf{M_c \geq M_{Ch} = 4\,(Y_e/m_H)^2\,(k_R/G)^{3/2} = 5{,}8\;Y_e^{\,2}\,M_O}$$

M_c increases because of thermonuclear burning in the surrounding shells, and M_{Ch} decreases because the lepton fraction in the core decreases. This is due to:

- neutronization of matter (i.e. $\mathbf{e^- + p}$ ® $\mathbf{n +} n_{\mathbf{e}}$),
- pair annihilation (i.e. $g + g$ ® $\mathbf{e^+} + \mathbf{e^-}$ ® $n_{\mathbf{e}} + n_{\mathbf{e}}$) and
- photodissociation of Fe nuclei (i.e. $g\ \mathbf{+\ {}^{56}Fe}$ ® $\mathbf{13\ {}^{4}He + 4n}$ or similar processes) followed by $\gamma + {}^4He \rightarrow 2n + 2p$

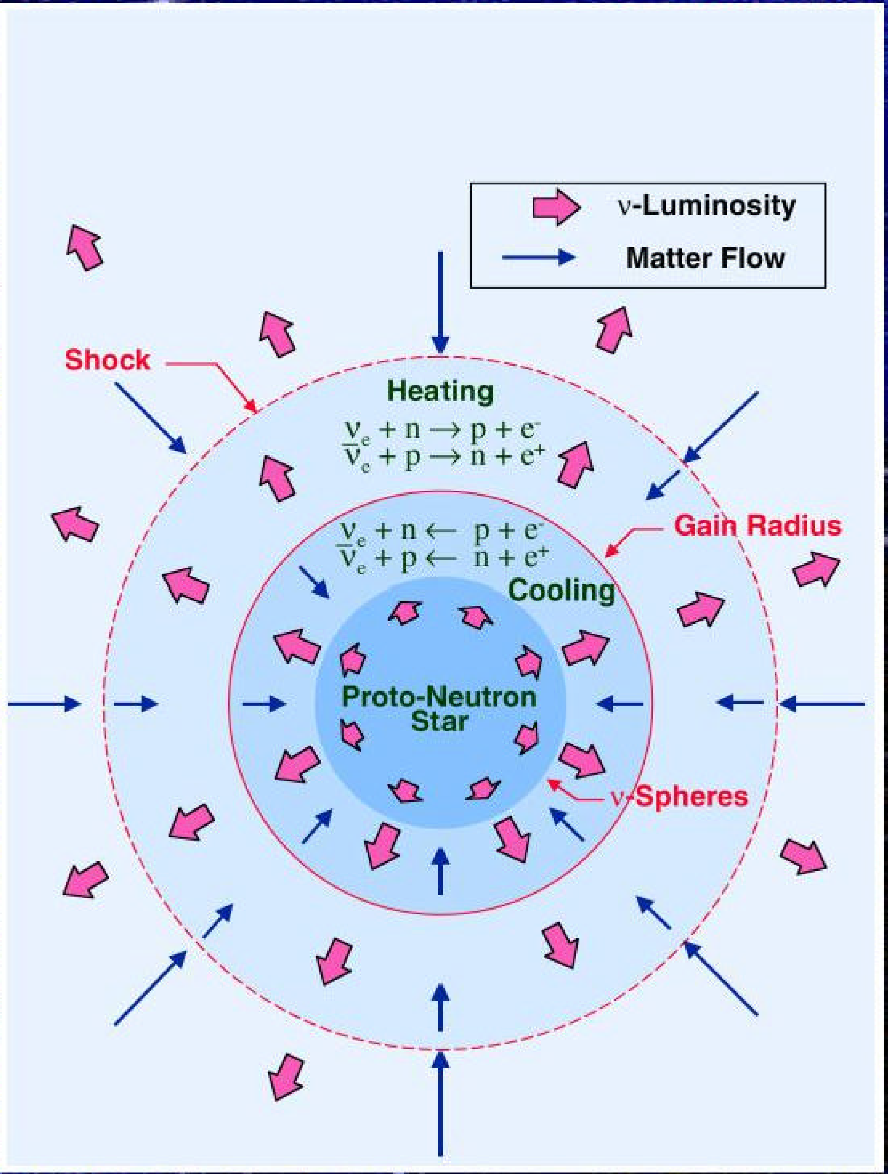
If the core collapse induces the envelope explosion we have a type II SN, if not we have a hidden source of collapse neutrinos.

Neutrinos to the Rescue

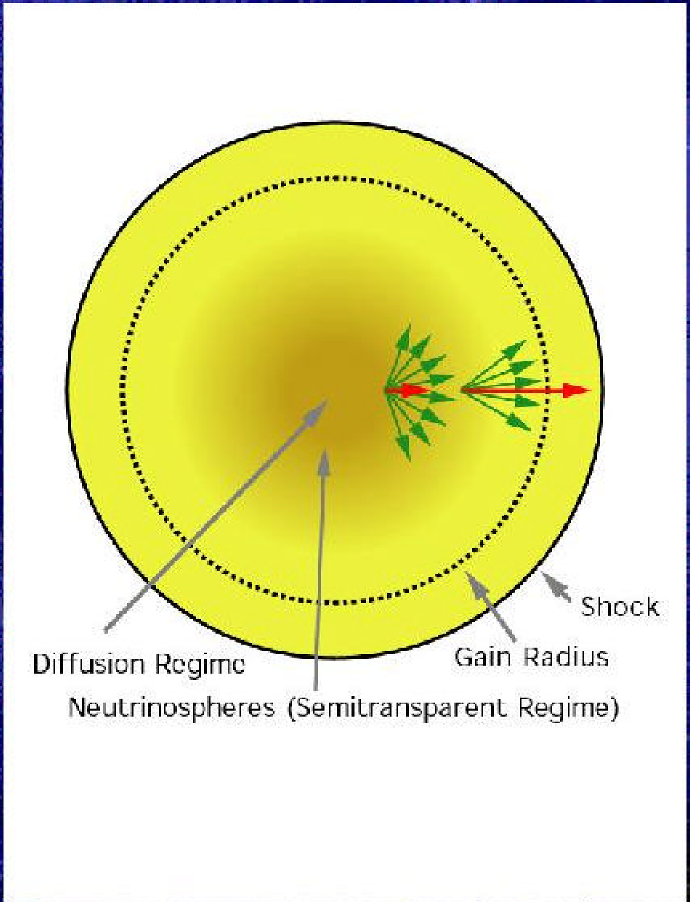

Neutrino heating increases pressure behind shock front

Picture adapted from Janka, astro-ph/0008432

Neutrino Heating Mechanism



Need Boltzmann Solution



$$\dot{\epsilon} = \frac{X_n}{\lambda_0^a}\frac{L_{\nu_e}}{4\pi r^2}\langle E_{\nu_e}^2\rangle\langle\frac{1}{\mathcal{F}}\rangle - \frac{X_p}{\bar{\lambda}_0^a}\frac{L_{\bar{\nu}_e}}{4\pi r^2}\langle E_{\bar{\nu}_e}^2\rangle\langle\frac{1}{\bar{\mathcal{F}}}\rangle$$

Decrease with Anisotropy

Approximations Used in the Past
e.g., MGFLD

NEUTRINOS FROM STELLAR COLLAPSES

➡ In a stellar core with $M_C \sim M_{Ch}$ there are about 10^{57} electrons, and
ence 10^{57} neutrinos are emitted if neutronization processes:

$$\mathbf{e^- + p} \text{ ® } \mathbf{n} + n_{\mathbf{e}} \quad \text{and} \quad \mathbf{e^- + (A, Z)} \text{ ® } \mathbf{(A, Z\text{-}1)} + n_{\mathbf{e}}$$

ully occur. Since these neutrinos have energy $E_\nu \sim 10$ MeV, the total
nergy emitted as ν is of order 10^{52} erg $\sim 10^{-2}\, M_C{}^2$.

➡ The energy emitted as neutrinos from e^+e^- annihilation processes:

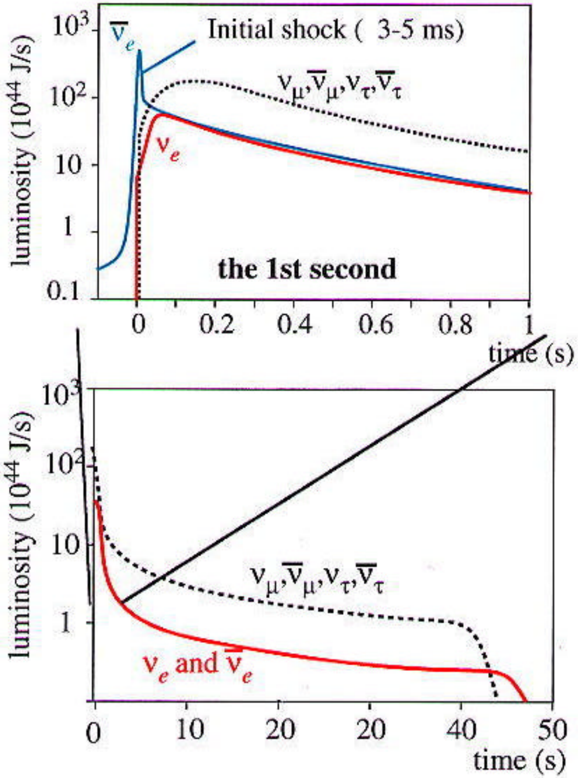
$$g + g \text{ ® } \mathbf{e^+ + e^-} \text{ ® } n_{\mathbf{e}} + \overline{n}_{\mathbf{e}}$$

s of order 20 to 30 times larger, namely $3 \cdot 10^{53}$ erg, which produces a
lux at the Earth of:

$$\Phi(n_{\mathbf{e}}, \overline{n}_{\mathbf{e}}) = \Phi_0(n_{\mathbf{e}}, \overline{n}_{\mathbf{e}})/4\pi d^2 = 3\ 10^{12}\ (n_{\mathbf{e}}, \overline{n}_{\mathbf{e}})\ \mathrm{cm}^{-2}$$

uring the burst duration which, according to most theoretical models,
s of the order of the free fall time of the collapse $\tau = (6\pi G\rho)^{-1/2}$

Neutrino masses from supernova explosion?



Burrows, Klein, Gandhi
PR D **45** (1992) 3361
Neutrino "light" curve

Supernova explosions produ
neutrinos of all the flavours.
Total duration 20-50 s
If longer than intrinsic durati
of the burst we can have
information on mass values

Delay due to non zero mass

$$\Delta t = 5.15\left(\frac{d}{10\ \mathrm{kpc}}\right)\left(\frac{m_\nu}{1\ \mathrm{eV}}\right)^2\left(\frac{10\ \mathrm{MeV}}{E_\nu}\right)^2\ \mathrm{ms}$$

From Supernova 1987A

$<m_\nu> < 10 - 20$ eV

limited by uncertainty in neutrino light curve and energy spectra.
Difficult to improve

Neutrinos and antineutrinos of all flavours are produced in the SN
Matter flavour conversions happen in the core and in outer envelopes
After leaving the envelope ν_1, ν_2 and ν_3 propagate. Vacuum oscillations.

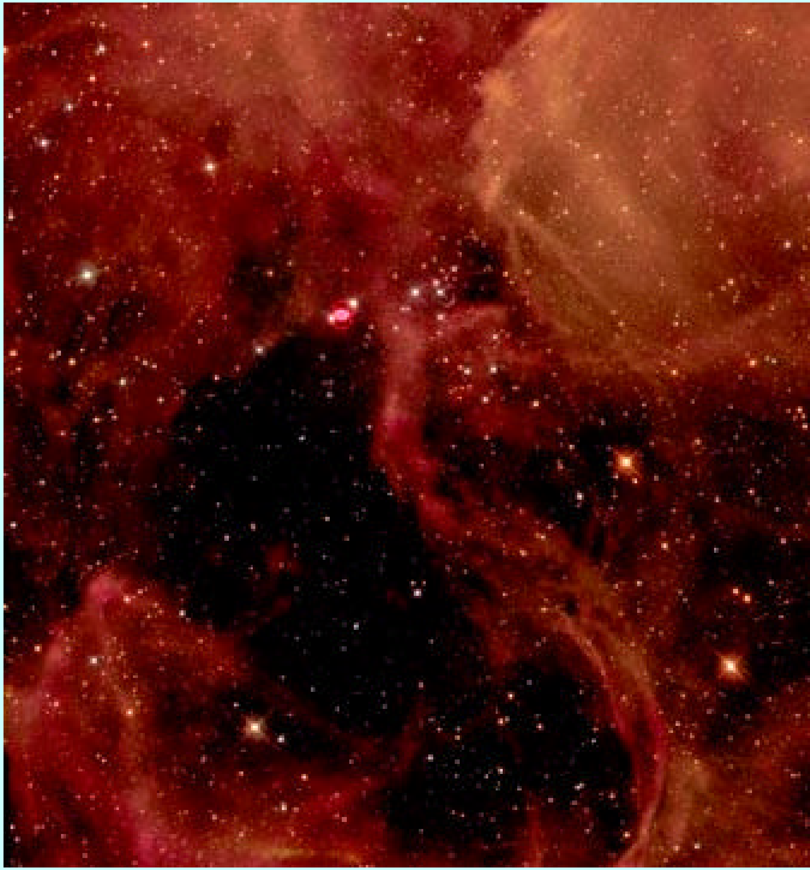
Measured (limited) mass is an average of the three masses with only partially known weights
Detecting neutrinos of a definite flavour does not give a limit on the "mass" of that flavour

INTRODUCTION

lmost 40 years ago the possibility to detect eutrinos from stellar collapses in our galaxy as suggested by Zatsepin & Domogatsky. ince that time several n observatories have een built and neutrino astronomy became a owerful tool to investigate both the core ollapse processes and the neutrino intrinsic roperties.

If a galactic SN occurs, several large-scale detectors, among them the LVD experiment in Italy, are expected to record information on this event.

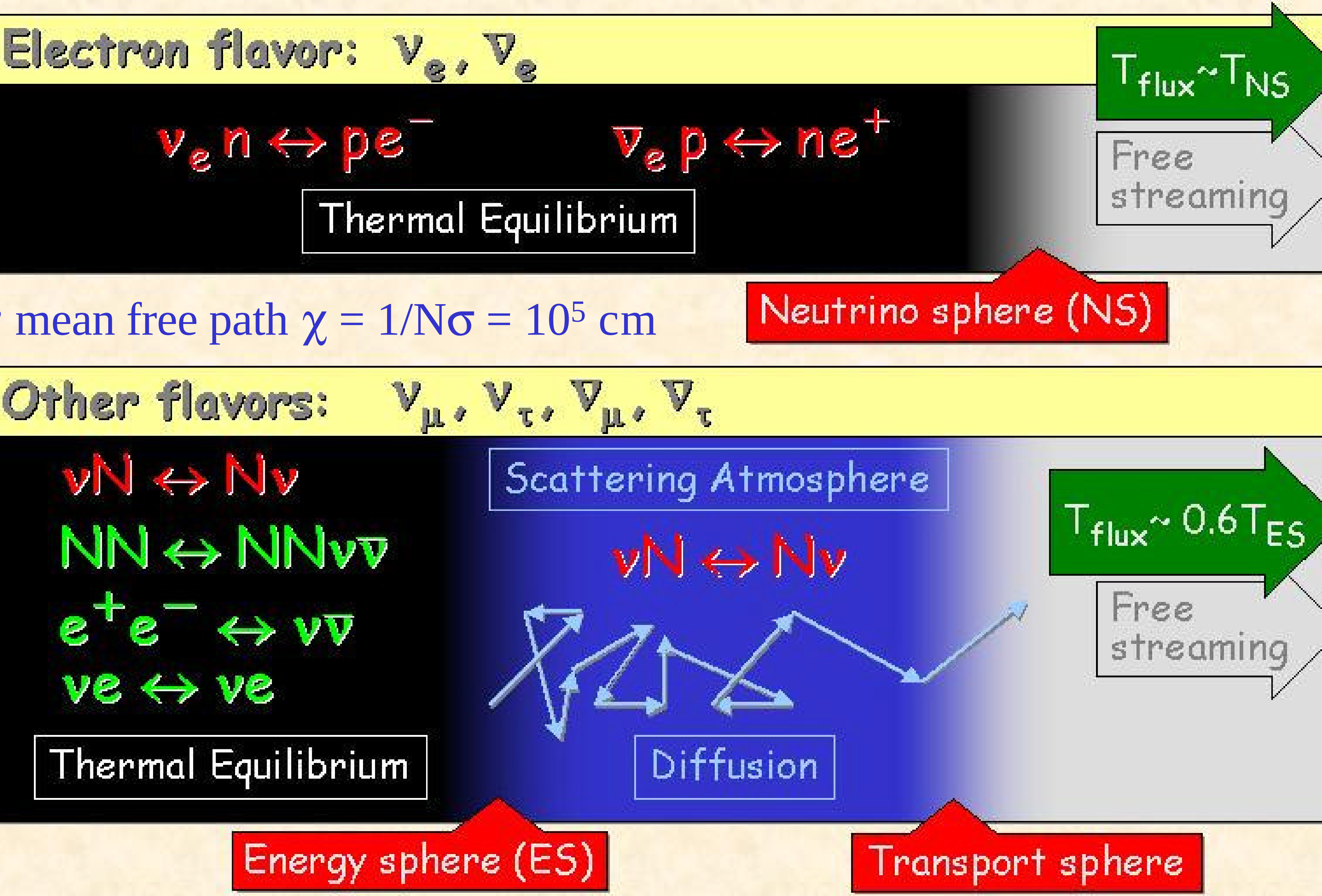
he survey of neutrino-bursts from alactic SN performed by the LVD etector, allows to give a new upper mit to the rate of stellar collapses in ur Galaxy.



SN 1987 A

Neutrino Spectra Formation

G.Raffelt
astro-ph/010525



Electron flavor: $\nu_e, \bar{\nu}_e$

$\nu_e n \leftrightarrow p e^-$ $\bar{\nu}_e p \leftrightarrow n e^+$

Thermal Equilibrium

$T_{flux} \sim T_{NS}$

Free streaming

Neutrino sphere (NS)

mean free path $\chi = 1/N\sigma = 10^5$ cm

Other flavors: $\nu_\mu, \nu_\tau, \bar{\nu}_\mu, \bar{\nu}_\tau$

$\nu N \leftrightarrow N \nu$

$NN \leftrightarrow NN\nu\bar{\nu}$

$e^+e^- \leftrightarrow \nu\bar{\nu}$

$\nu e \leftrightarrow \nu e$

Thermal Equilibrium

Scattering Atmosphere

$\nu N \leftrightarrow N \nu$

Diffusion

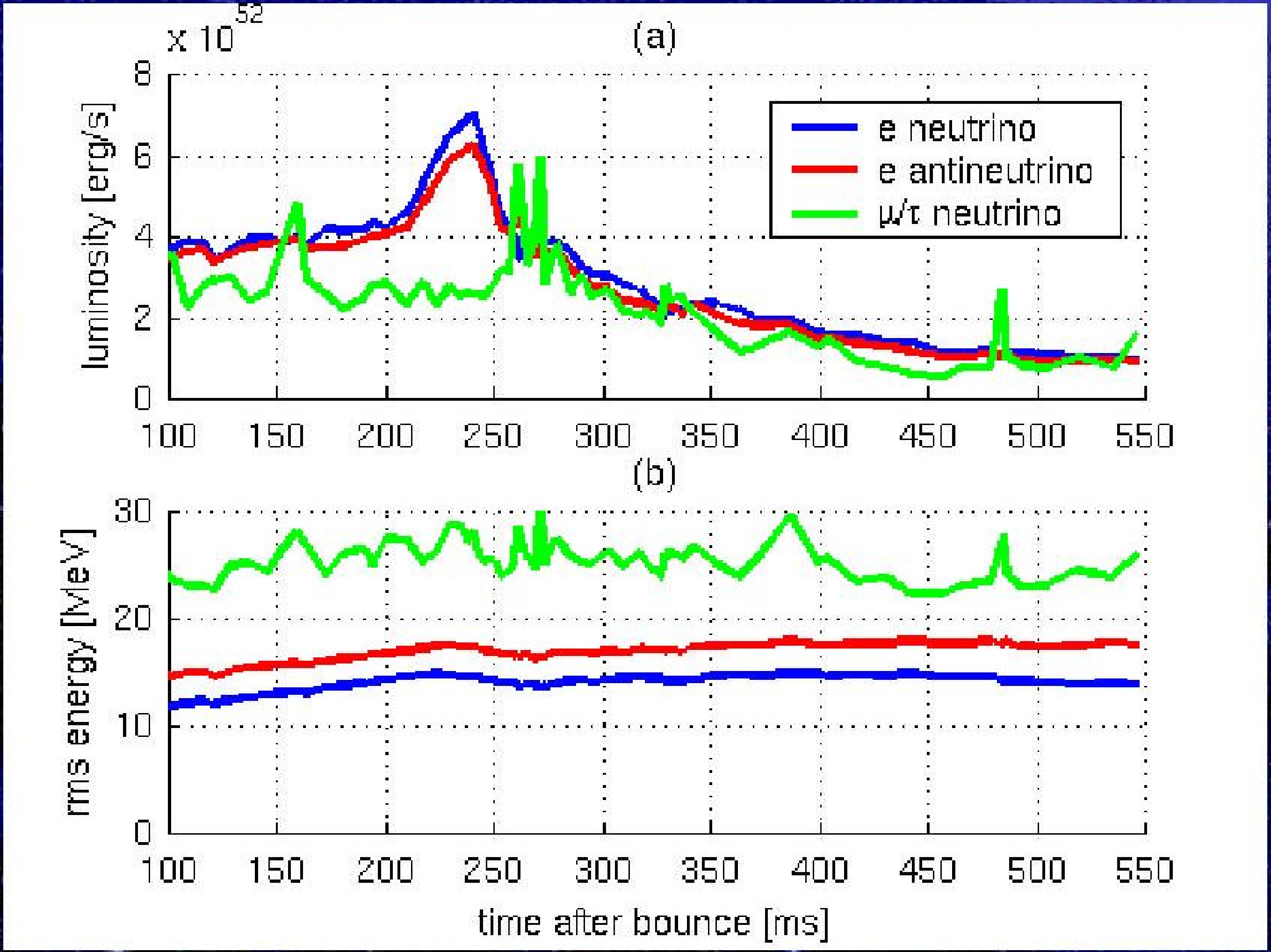
$T_{flux} \sim 0.6\, T_{ES}$

Free streaming

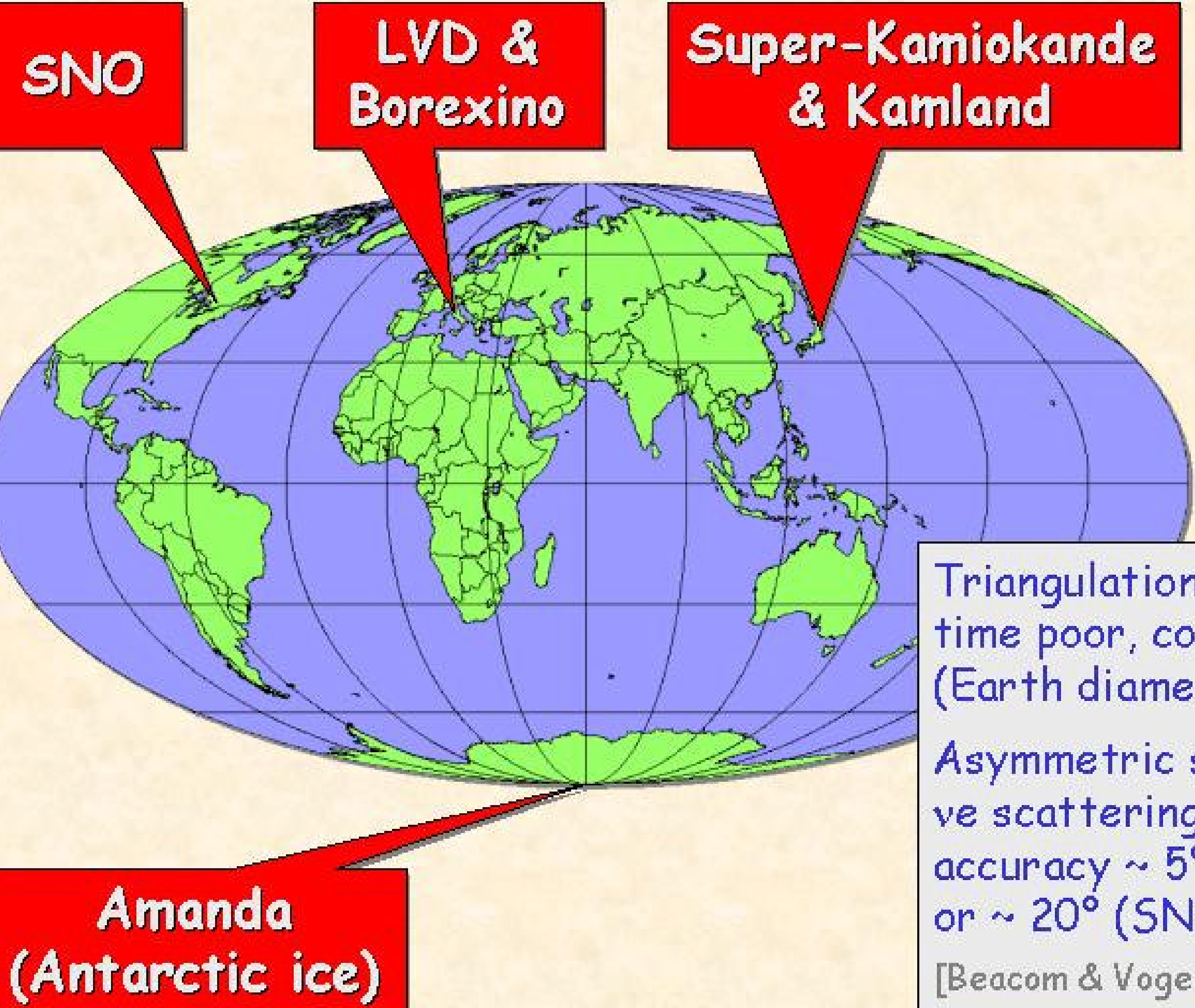
Energy sphere (ES)

Transport sphere

Luminosities RMS Energies



Large Detectors for SN Neutrinos



SNO

LVD & Borexino

Super-Kamiokande & Kamland

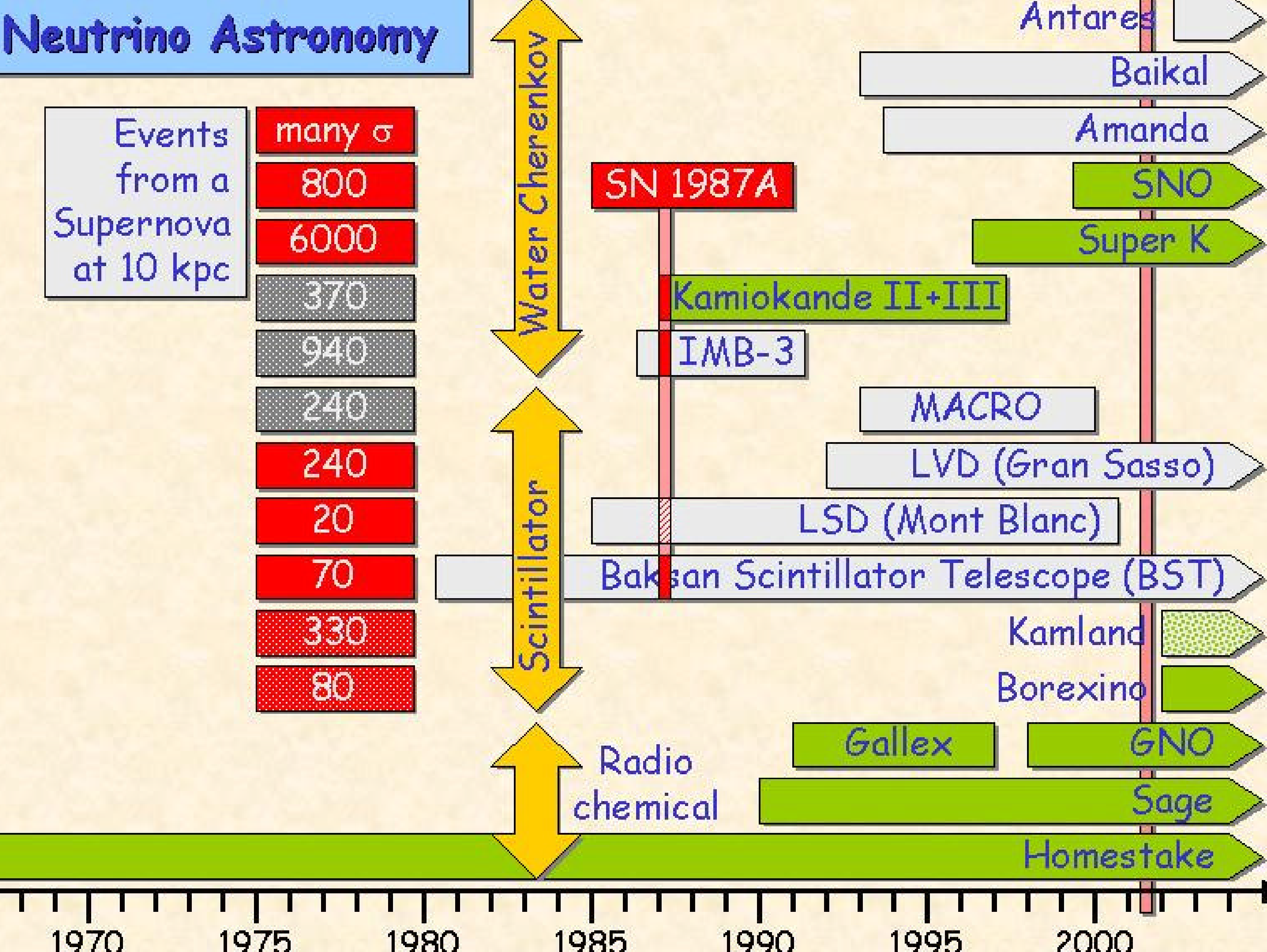
Amanda (Antarctic ice)

Triangulation by arrival time poor, cos(θ) ~ 0.5 (Earth diameter ~ 42 ms)

Asymmetric signal from νe scattering: Pointing accuracy ~ 5° (SuperK) or ~ 20° (SNO)

[Beacom & Vogel, hep-ph/9806311

Neutrino Astronomy



Events from a Supernova at 10 kpc	
	Antares
	Baikal
many σ	Amanda
800	SNO
6000	Super K
370	Kamiokande II+III
940	IMB-3
240	MACRO
240	LVD (Gran Sasso)
20	LSD (Mont Blanc)
70	Baksan Scintillator Telescope (BST)
330	Kamland
80	Borexino
	Gallex
	GNO
	Sage
	Homestake

SUMMARY OF SN NEUTRINO DETECTOR TYPES

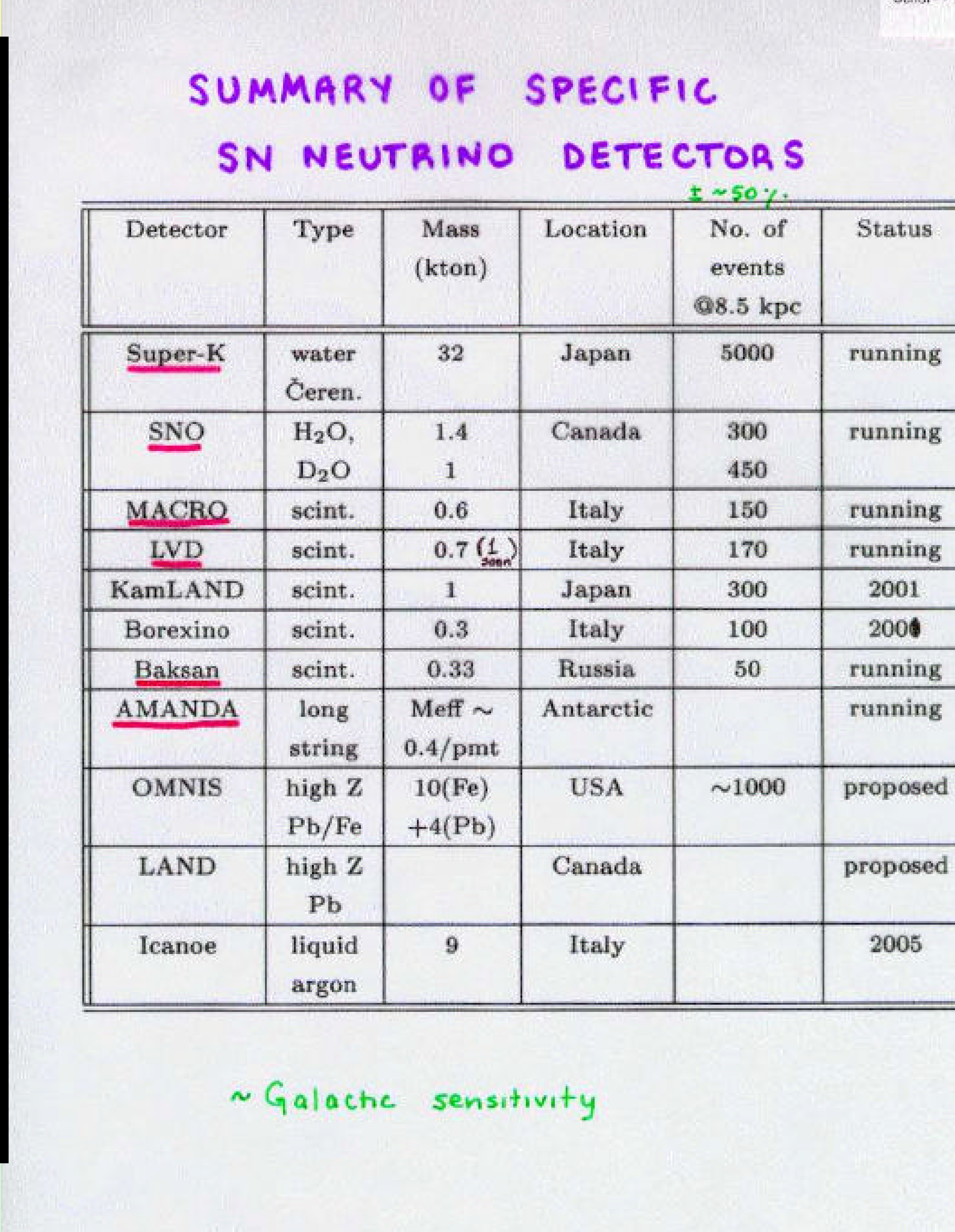
Detector type	Material	Energy	Time	Point	Flavor
scintillator	C,H	y	y	n	$\bar{\nu}_e$
water Čerenkov	H_20	y	y	y	$\bar{\nu}_e$
heavy water	D_20	NC: n	y	n	all
		CC: y	y	y	$\nu_e, \bar{\nu}_e$
long string water Čerenkov	H_2O	n	y	n	$\bar{\nu}_e$
liquid argon	Ar	y	y	y	ν_e
high Z/neutron	Fe Pb	n	y	n	all
radio-chemical	^{37}Cl ^{127}I ^{71}Ga	n	n	n	ν_e

- primary sensitivity to $\bar{\nu}_e$
- NC for heavy water, neutron
- pointing for water Ch., heavy water, argon
- all real-time except radiochemical
- all have energy resolution except $\left\{\begin{array}{l}\text{long string}\\ \text{neutron}\\ \text{radiochemical}\end{array}\right.$

Beyond material, mass and
epth, a supernova neutrino
elescope must have:

Buffer adequate to handle
igh throughoutput
Short deadtime
Accurate absolute and
elative timing
Good energy resolution
Low maintenance cost
And a high duty cycle

A Burrows,
Phys.Rev.D,45,3361 (1992)



SUMMARY OF SPECIFIC
SN NEUTRINO DETECTORS

± ~50%

Detector	Type	Mass (kton)	Location	No. of events @8.5 kpc	Status
Super-K	water Čeren.	32	Japan	5000	running
SNO	H_2O, D_2O	1.4 1	Canada	300 450	running
MACRO	scint.	0.6	Italy	150	running
LVD	scint.	0.7 (1 soon)	Italy	170	running
KamLAND	scint.	1	Japan	300	2001
Borexino	scint.	0.3	Italy	100	200[illegible]
Baksan	scint.	0.33	Russia	50	running
AMANDA	long string	Meff ~ 0.4/pmt	Antarctic		running
OMNIS	high Z Pb/Fe	10(Fe) +4(Pb)	USA	~1000	proposed
LAND	high Z Pb		Canada		proposed
Icanoe	liquid argon	9	Italy		2005

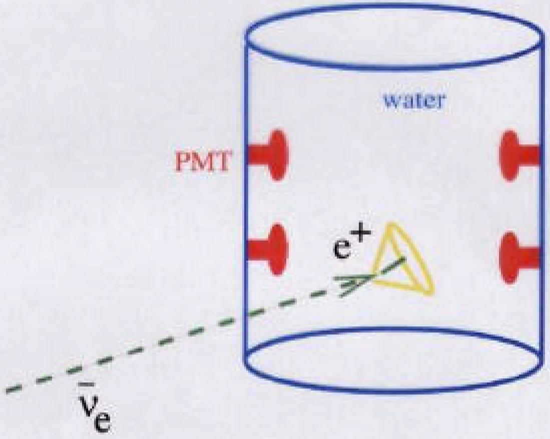
~ Galactic sensitivity

WATER CHERENKOV DETECTORS

Volume of clear water viewed by PMTs

CC $\bar{\nu}_e + p \rightarrow \boxed{e^+} + n$ still dominates

Also: CC $\left\{ \begin{array}{l} \nu_e + {}^{16}O \rightarrow {}^{16}F + e^- \\ \nu_e + {}^{18}O \rightarrow {}^{18}F + e^- \\ \bar{\nu}_e + {}^{16}O \rightarrow {}^{16}N + e^- \end{array} \right\}$, NC $\nu_x + {}^{16}O \rightarrow \nu_x' + {}^{16}O$



NC, CC $\nu_x + e^- \rightarrow \nu_x + \boxed{e^-}$ few percent

POINTING $\Delta\theta \sim 25°$

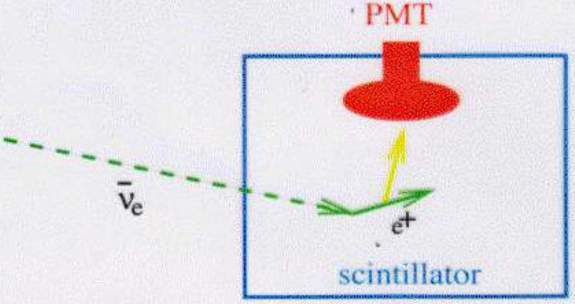
$\nu_e \cdots\rightarrow e^-$ direction from Ch. cone $\delta\theta \gtrsim \frac{25°}{\sqrt{n}}$

Kamiokande, IMB, Super-Kamiokande, part of SNO

$\gtrsim$ 5000 events
@ 8.5 kpc

SCINTILLATION DETECTORS

Liquid scintillator "C_nH_{2n}" volume
viewed by PMTs



INVERSE BETA DECAY

$E_{e^+} = E_{\bar{\nu}_e} - 1.3$ MeV

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

180 μs $\hookrightarrow n + p \rightarrow d + \boxed{\gamma}$ 2.2 MeV

NC EXCITATION OF ^{12}C

NC $\nu_x + {}^{12}C \rightarrow \nu_x + {}^{12}C^*$

15.1 MeV

$\hookrightarrow {}^{12}C + \boxed{\gamma}$ ~5%

ELASTIC SCATTERING

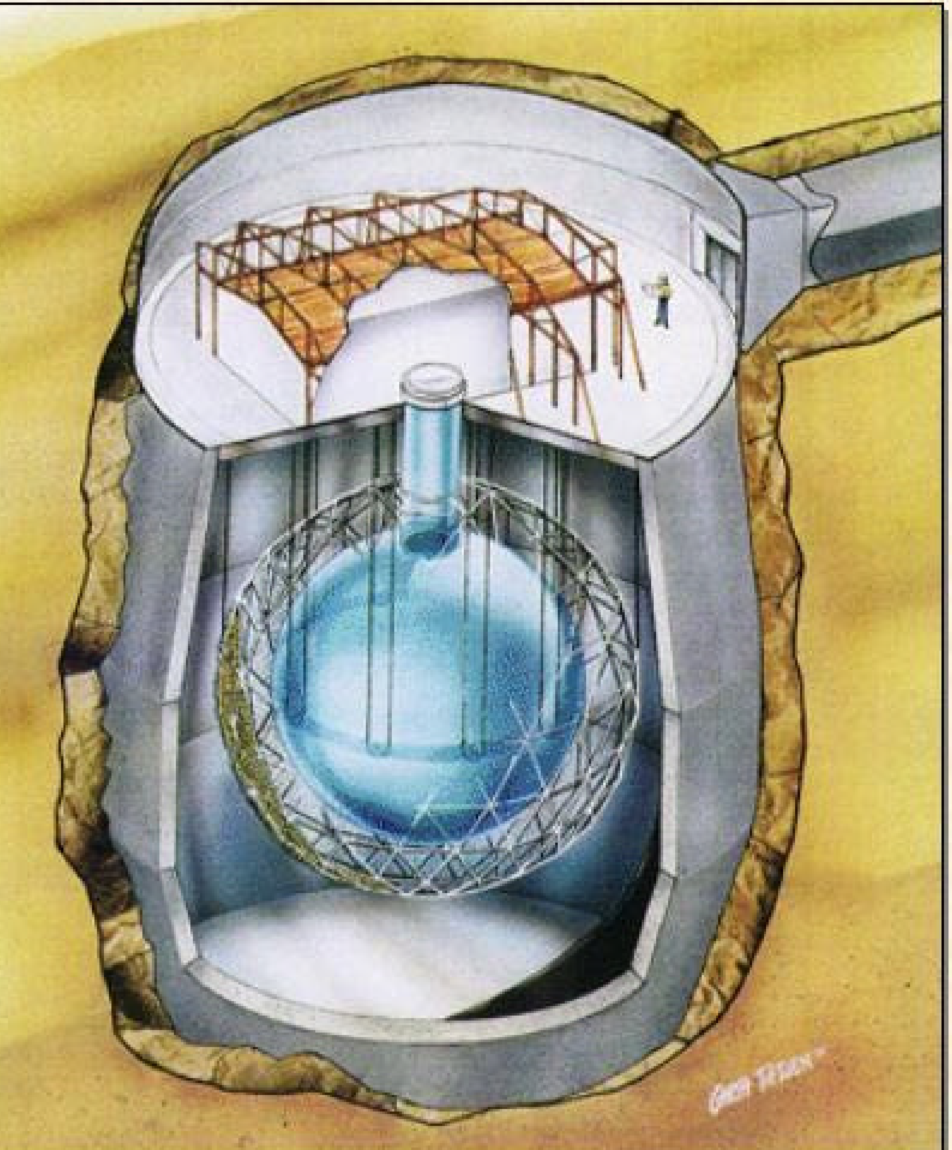
NC, CC $\nu_x + e^- \rightarrow \nu_x + \boxed{e^-}$ ~few %

(Almost) NO POINTING (but: see Chooz
hep-ex/990601

Examples: Mont Blanc, Baksan, Palo Verde, Chooz

MACRO, LVD, Borexino, KamLAND

Sudbury Neutrino Observatory (SNO)
(1000 tons of heavy water)



Expected events from
SN at 10 kpc
(no flavor oscillations)

Heavy water (1 kt)	Events:
CC: $\nu_e + d \to p + p + e^-$	72
CC: $\bar{\nu}_e + d \to n + n + e^+$	138
NC: $\nu_e + d \to \nu_e + p + n$	30
NC: $\bar{\nu}_e + d \to \bar{\nu}_e + p + n$	32
NC: $\nu_x + d \to \nu_x + p + n$	164

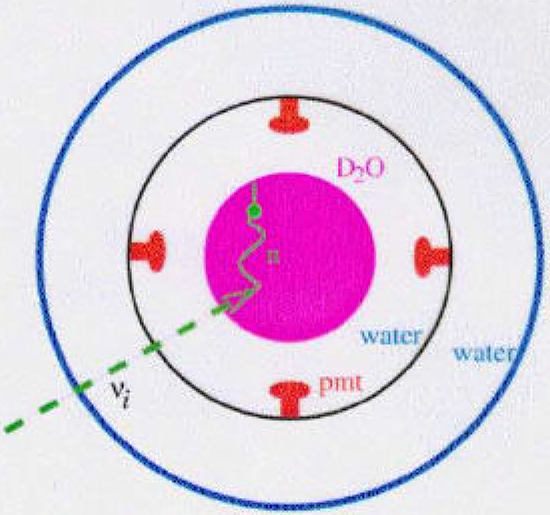
Light water (1.4 kt)	Events:
CC: $\bar{\nu}_e + p \to n + e^+$	331

HEAVY WATER DETECTORS SN

D_2O viewed by PMTs + neutron detection

$$\text{CC} \left\{ \begin{array}{l} \nu_e + d \rightarrow p + p + \boxed{e^-} \\ \bar{\nu}_e + d \rightarrow \boxed{n + n} + \boxed{e^+} \end{array} \right\}$$

$$\text{NC} \left\{ \begin{array}{l} \nu_x + d \rightarrow \boxed{n} + p + \nu_x \\ \bar{\nu}_x + d \rightarrow \boxed{n} + p + \bar{\nu}_x \end{array} \right\}$$

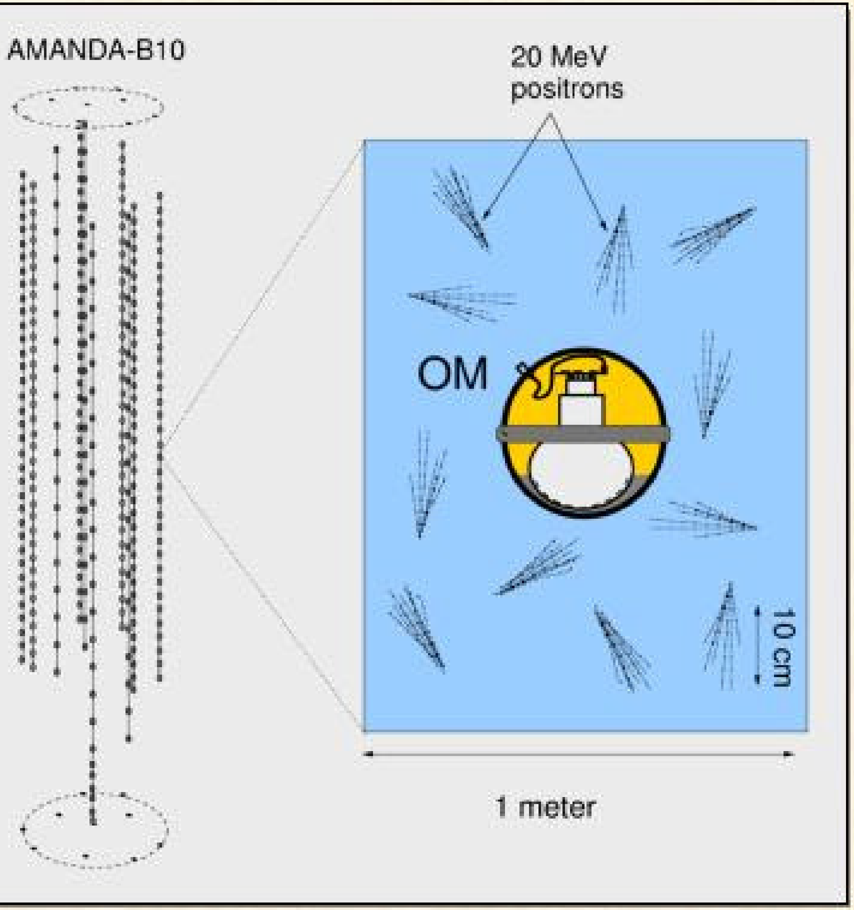


VERY GOOD NC SENSITIVITY

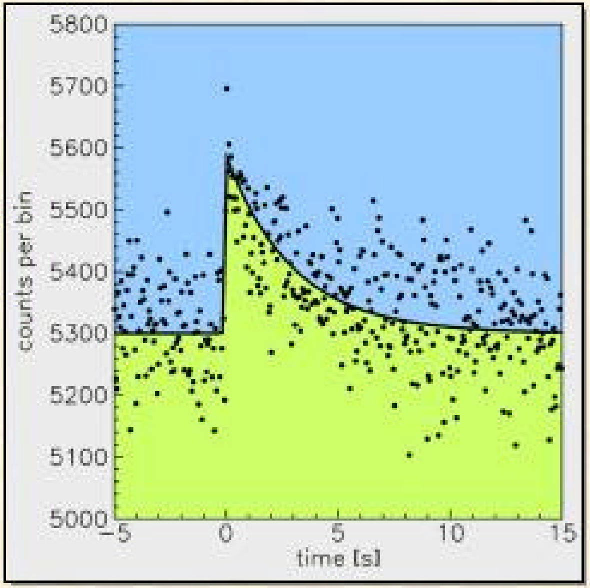
⇒ sensitivity to ν mass, osc

SNO : 1 kton D_2O , few hundred each of
1.4 kton H_2O $\bar{\nu}_e p$, NC, CC breakup
for collapse @ 8.5 k

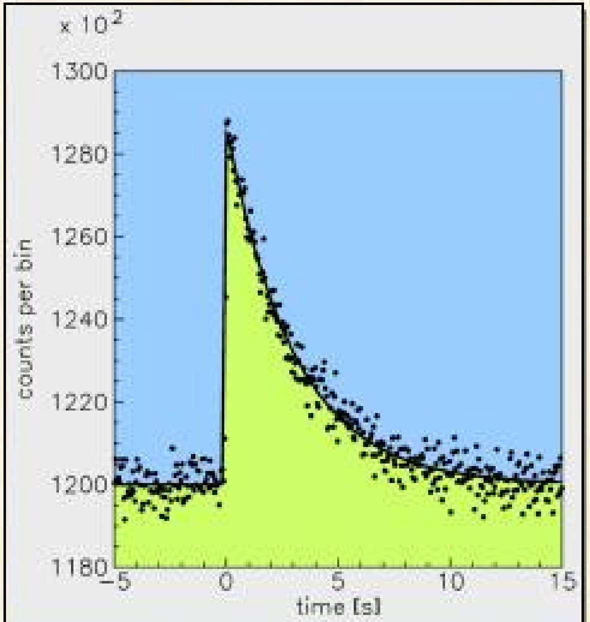
Amanda/IceCube as a Supernova Detector



Each optical module (OM) picks up Cherenkov light from its neighborhood. SN appears as correlated "noise" between OMs



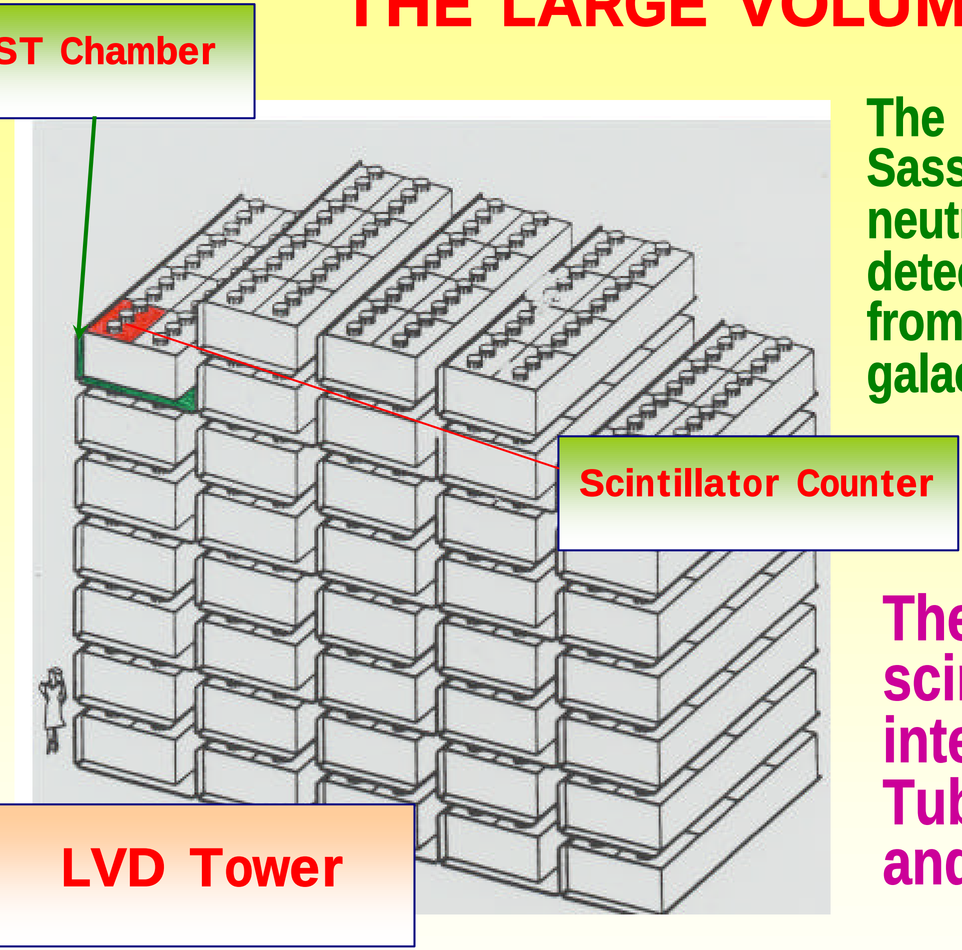
SN @ 8.5 kp
Signal in
Amanda



SN @ 8.5 kp
Signal in
Ice Cube

Amanda
Collaboration
(2001)

THE LARGE VOLUME DETECTOR



The LVD experiment, located in the Gran Sasso Underground Laboratory (Italy) is a neutrino telescope mainly designed to detect the burst of low energy neutrinos from a gravitational stellar collapse of a galactic object.

The apparatus, consisting of 840 scintillation counters (1.5 m^3 each) interleaved by Limited Streamer Tubes, is arranged in a compact and modular geometry.

The experiment, operating with increasing active mass since 1992, is now in the final configuration with an active mass of M=1000 tons of liquid scintillator.

The energy threshold E_{th} of the counters is divided in 2 subsets:
- for the external counters E_{th} = 7 MeV,
- For the internal counters (better shielded from the rock radioactivity) E_{th} = 4 MeV,

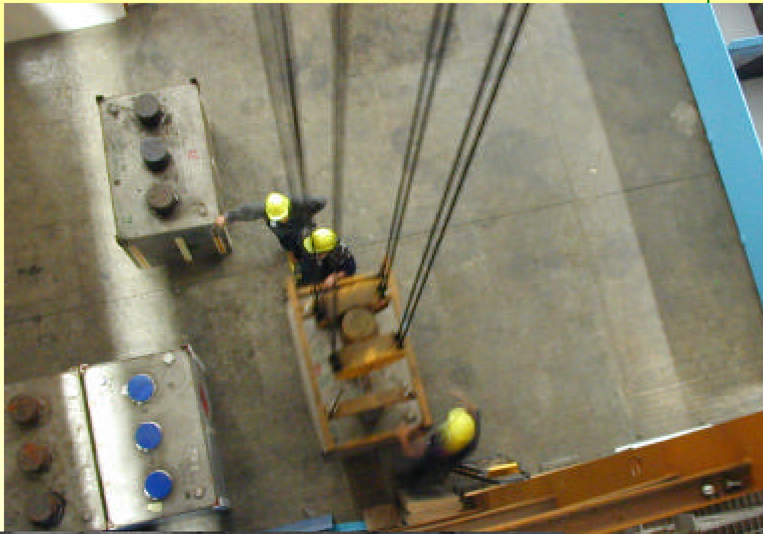
The main purpose of the telescope is to detect neutrinos from gravitational stellar collapse.

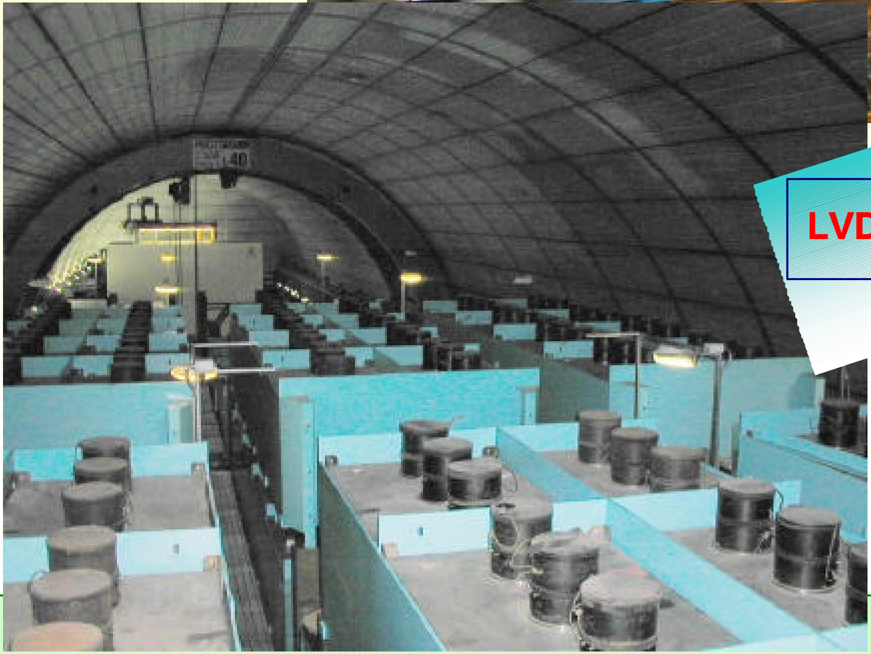
⬇

Large duty cycle and high modularity are required to reach the best performances in the galaxy survey.

The LVD sensitivity is high enough to monitor SN events occurring in any place of our galaxy, and can reach the Magellanic clouds.

Assembling





LVD Top View

NEUTRINO DETECTION IN LVD

Possible ways of neutrinos interactions in the LVD scintillator are the absorption interaction, he charged and neutral currents reactions on ^{2}C and finally the n-e scattering .

However the most relevant mechanism is the b nverse decay on scintillator protons, observed hrough 2 detectable signals:

- prompt signal due to e^+ @ $E=E_n-1.8MeV+2m_ec^2$ followed with an average delay Dt=200 ms by
- the signal of neutron capture @ $E_g=2.2$ MeV

$\bar{n}_e$ **tagging** through detection of delayed γ from n capture at low energy threshold : efficiency 60%.

n **interactions at LVD**
$\bar{n}_e + p$ ® $n + e^+$
$n_i\,(n_x) + e^-$ ® $n_i\,(n_x) + e^-$
$n_e + {}^{12}C$ ® ${}^{12}N + e^-$
$\bar{n}_e + {}^{12}C$ ® ${}^{12}B + e^+$
$n_i\,(n_x) + {}^{12}C$ ® $n_i(n_x) + g + {}^{12}C$

Neutral and **Charge** **currents** interactions c carbon nuclei: potenti for ν oscillation studie

The expected number of $n_e\overline{p}$ interactions in LVD for a standard collapse normalized @ D=10 kpc and T_n=3.5 MeV [Burrows, Klein, Gandhi, 1999] is :

$$N \approx 200 \cdot \frac{M_{LVD}}{1\,kton} \cdot \frac{T}{3.5\,MeV} \cdot \left(\frac{D}{10\,kpc}\right)^{-2}$$

STEP 1 Burst Candidate Selection

The LVD neutrino burst candidate selection basically consists of an algorithm which analyzes on line all possible clusters initiated by each single pulse belonging to the events sequence.

For a selected cluster of multiplicity m and duration Δt (<200 s), the imitation frequency FIM is calculated assuming Poisson distribution of the background with average value f given by the measured value.

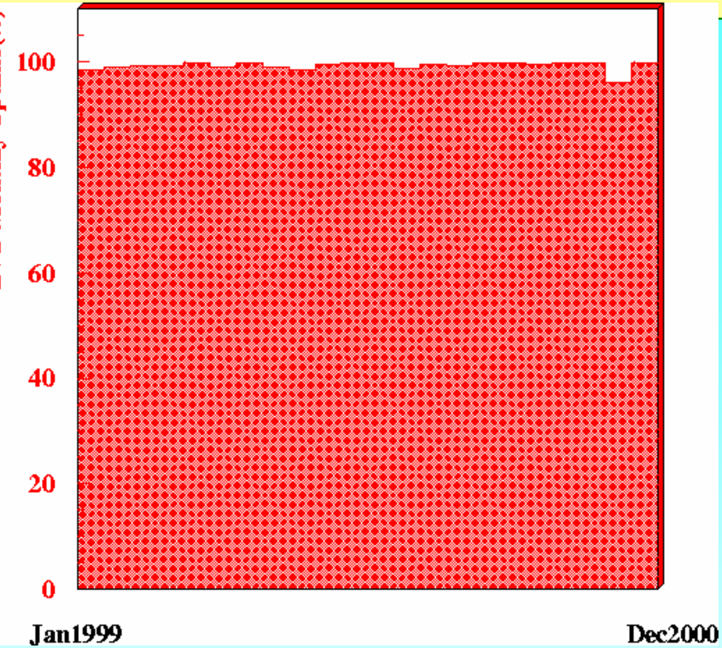
$$FIM = FIM(m, ?\, t, f)$$

STEP 2 Consistency Checks

After the statistical selection a complete analysis of interesting candidate , i.e. those having a FIM <1 event/year is performed in order to check its consistency with a real ν burst by:

- the study of topological distribution of pulses inside the detector
- the energy spectrum of pulses in the cluster
- the time distribution of delayed energy pulses due to neutron capture following $\bar{\nu}_e$ interaction.

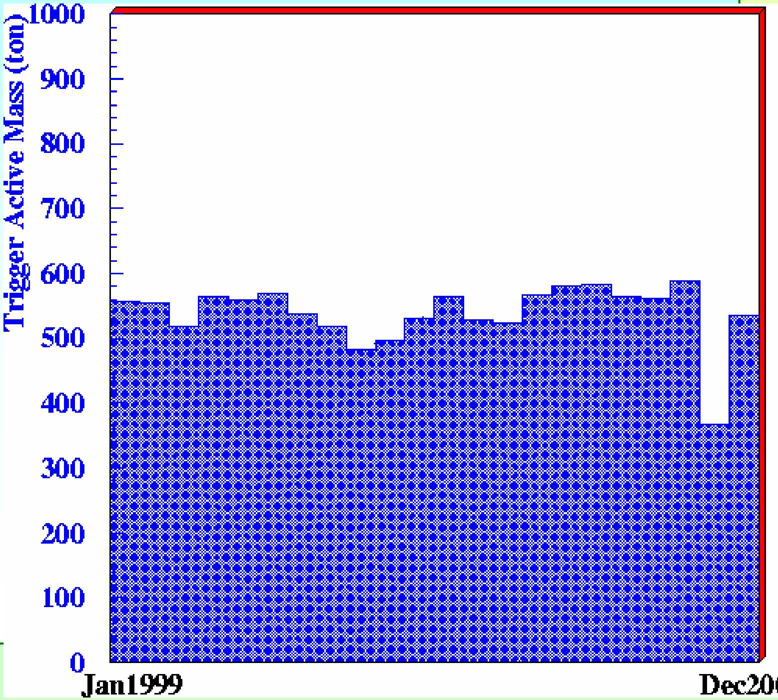
RESULTS



Since March 16th 1999 to December 11th 2000, 592 days of live time, 4278282 pulses in the energy range 7-100 MeV have been recorded and processed. Rate of background pulses is f=0.084 event/s.

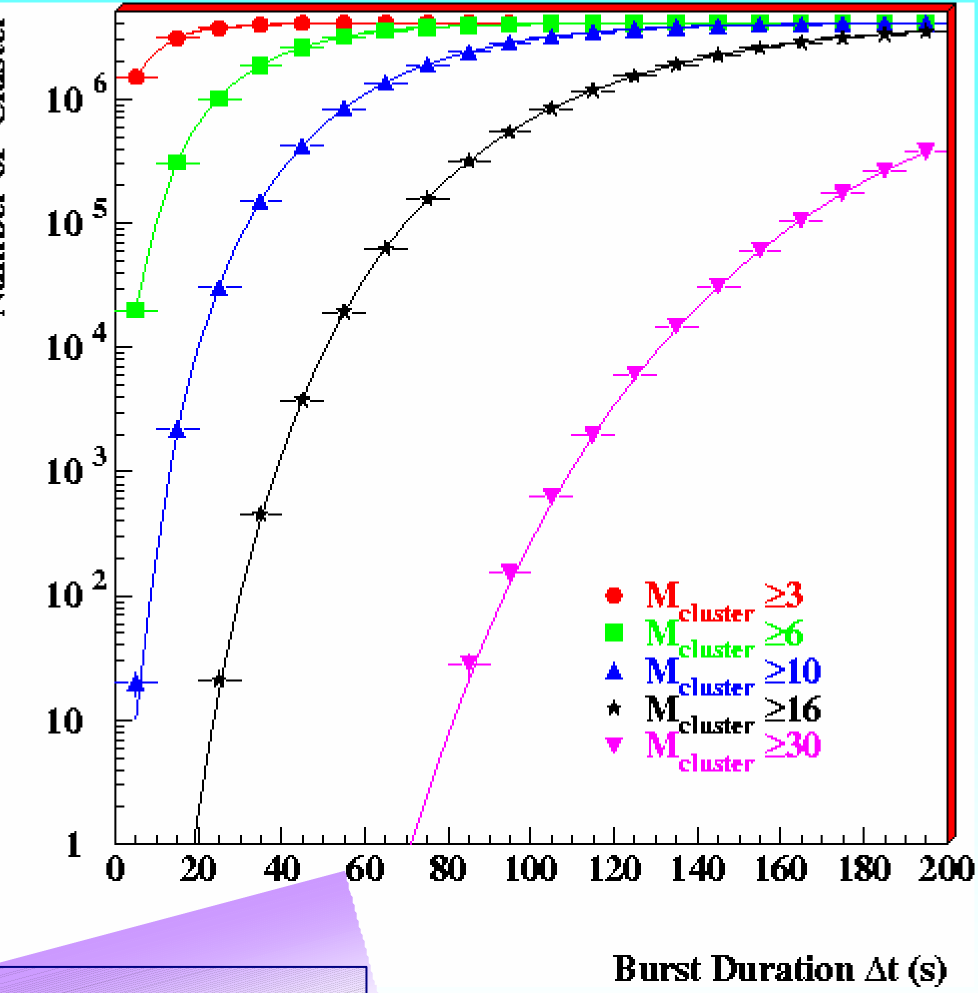
LVD duty cycle, monthly averaged and covering the period under analysis, is presented. Up today the new DAQ system avoids data taking interruption: uptime reaches value > 99.7 %.

The figure shows the monthly averaged active mass in the LVD detector for the same period. Counters showing malfunction problems have not been included on the basis of a complete run by run screening (LVD Global Data Base file).



All clusters of events have been scanned searching for candidate with low imitation frequency FIM.

Clusters Analysis

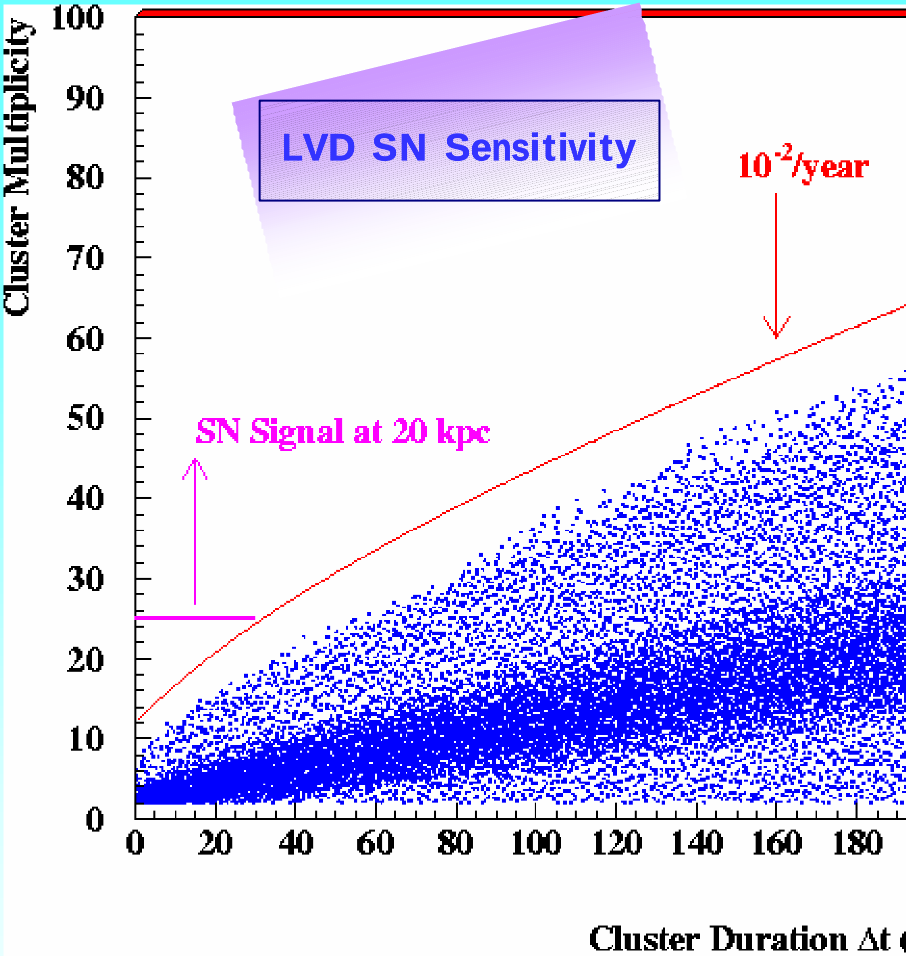


The figure shows the multiplicity distributions of all monitored clusters versus their time duration between 0 and 200 s. Comparison of data results (different color markers) with expectations (solid color lines) from Poissonian fluctuations of the background is presented.

The quite good agreement between experimental data and expectations at different cluster multiplicity and duration confirms directly the stability of the detector response even in a long term and multiple run analysis.

ach detected cluster is represented as a
ot in the Multiplicity (m) vs. Duration (Dt)
lane. The sensitivity of the detector at the
evel of 1 event every 100 years is shown.

Taking into account the average active mass during the monitored period at the distance D=20 kpc and T_n=3.5 MeV the expected number of interactions in LVD N ~ 25 is estimated . Even for duration of ~10 s we are well inside the sensitivity limits of the detector.



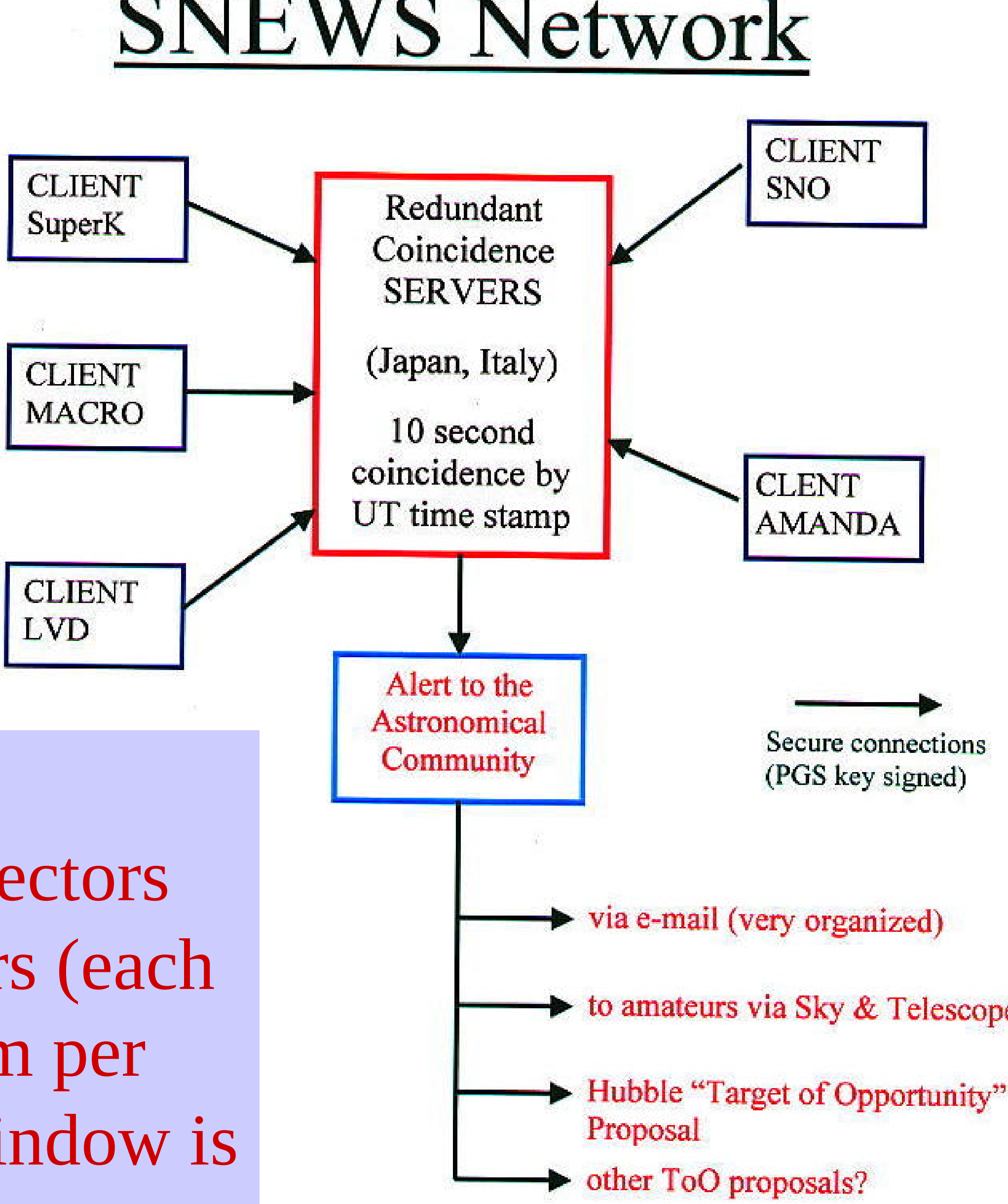
These results clearly show that no significant signal from a SN in our galaxy has been recorded.

ncluding previous reported results for a total of 2691 days of observation the upper
mit @ 90 % C.L. to the rate of gravitational stellar collapse in our Galaxy can be set:

90 % c.l. Upper Limit 0.3 event/year

LVD 1 kton STATUS & PROSPECTS

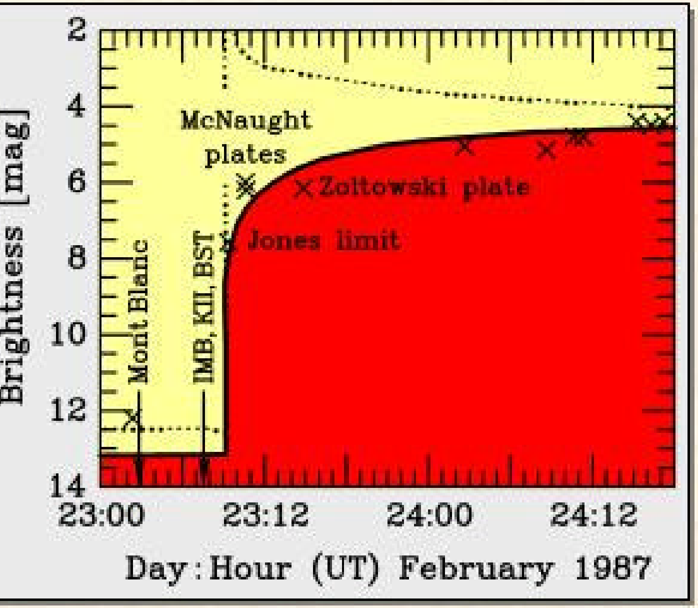
- **M=1 KTON** January 2001 LVD reaches its final configuration with a sensitive mass M = 1 kton.
- **DAQ UPGRADE** A complete upgrade of DAQ system has been realized in order to ensure both high modularity either the possibility to insert/remove counters without data taking interruptions. Apparatus maintenance is no more a problem even in case of hard work on detector.
- **SHIELDING** June 2001 An additional iron shielding on the top layer of the telescope reduced counting rate of upper counters of a factor > 2.
- **SNEWS** LVD is member of the Supernova Early Warning System project which involves an international collaboration including current SN neutrino detectors (SUPERKAMIOKANDE and SNO). The aim of the project is to provide an automated and early alarm to the astronomers community at time of SN event by the coincidence between alarm candidates of different detectors. Preliminary tests on detector and WEB interconnectivity have been successfully done.
- **GD SCINTILLATOR** The possibility of low cost and stable Gd doped scintillator is under exploration for future deployment at least in external counters.



The number of accidental oincidences between 2 detectors over 3 to 5 running detectors (each with a trigger rate of 1 alarm per week) within a 10 s time window is of the order of

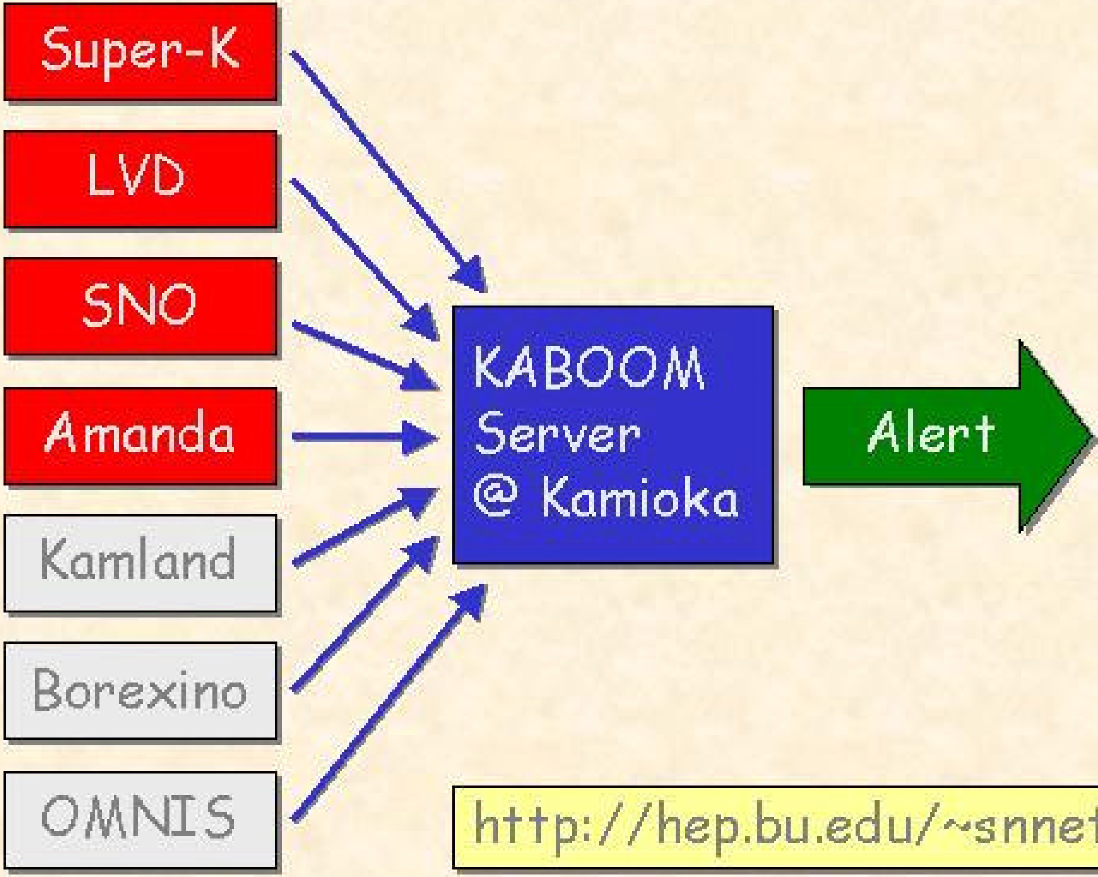
1 coincidence per 100 years

SuperNova Early Warning System (SNEWS)



Supernova 1987A
Early Light Curve

Neutrino observation can alert astronomers several hours in advance to SN. To avoid false alarms, require alarm from at least two experiments.



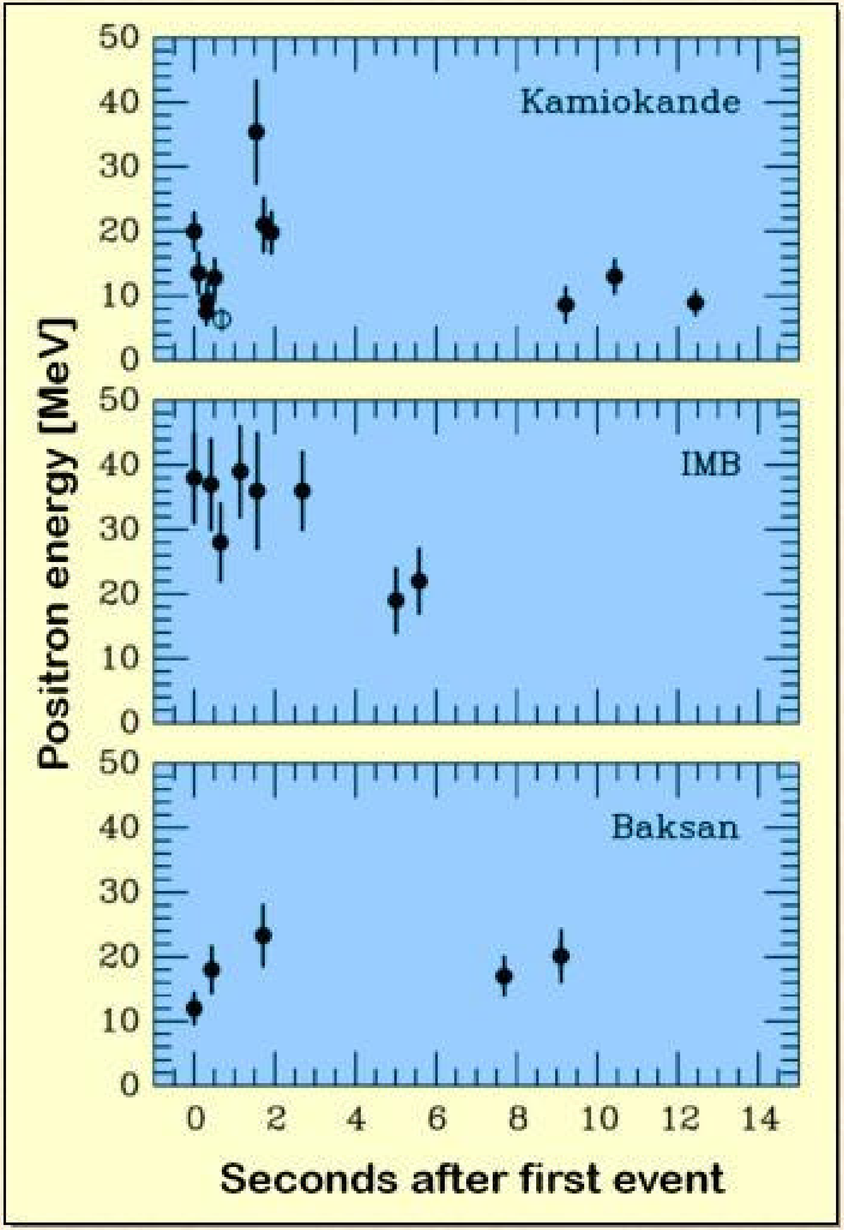
http://hep.bu.edu/~snnet

Sanduleak -69 202

Supernova 1987

23 February 198

Neutrino Signal of Supernova 1987A



Kamiokande (Japan)
Water Cherenkov detector
Clock uncertainty ±1 min

Irvine-Michigan-Brookhaven (USA)
Water Cherenkov detector
Clock uncertainty ±50 ms

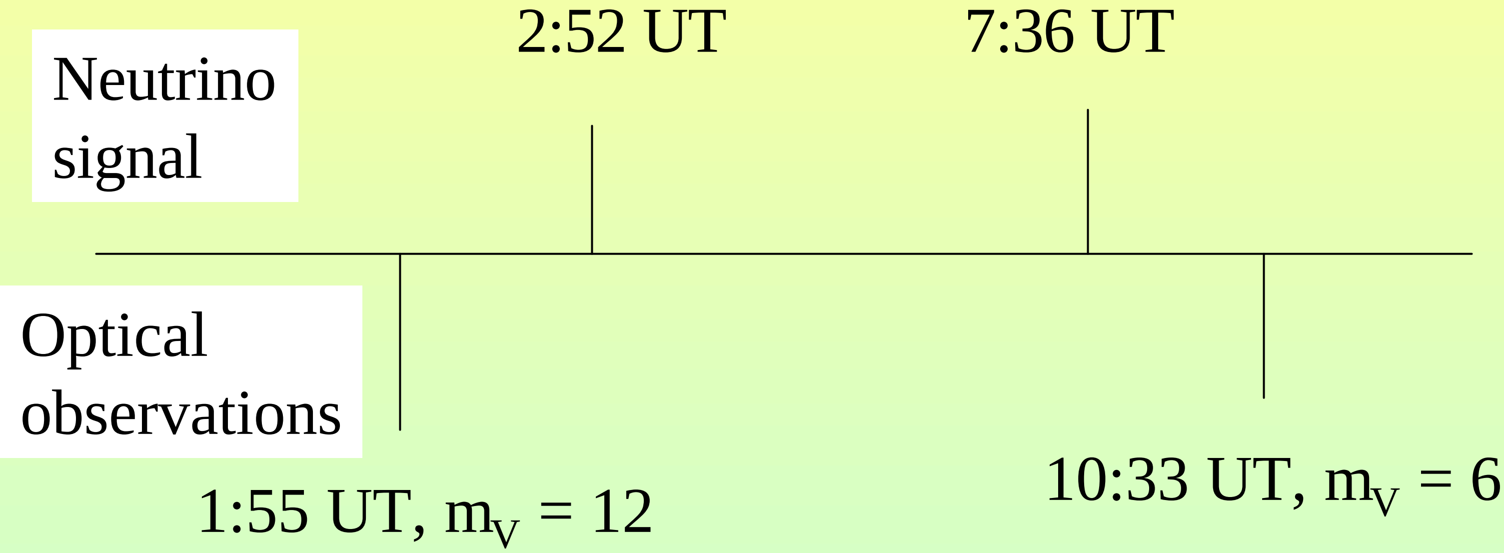
Baksan Scintillator Telescope (Soviet Union)
Clock uncertainty +2/-54 s

Within clock uncertainties, signals are contemporaneous

NEUTRINOS FROM SN 1987A

Progenitor star Sanduleak –69202: B3 Ia, 20-25 M_O

2 Bangs reported by 4 underground laboratories



Neutrino signal

2:52 UT

7:36 UT

Optical observations

1:55 UT, $m_V = 12$

10:33 UT, $m_V = 6$

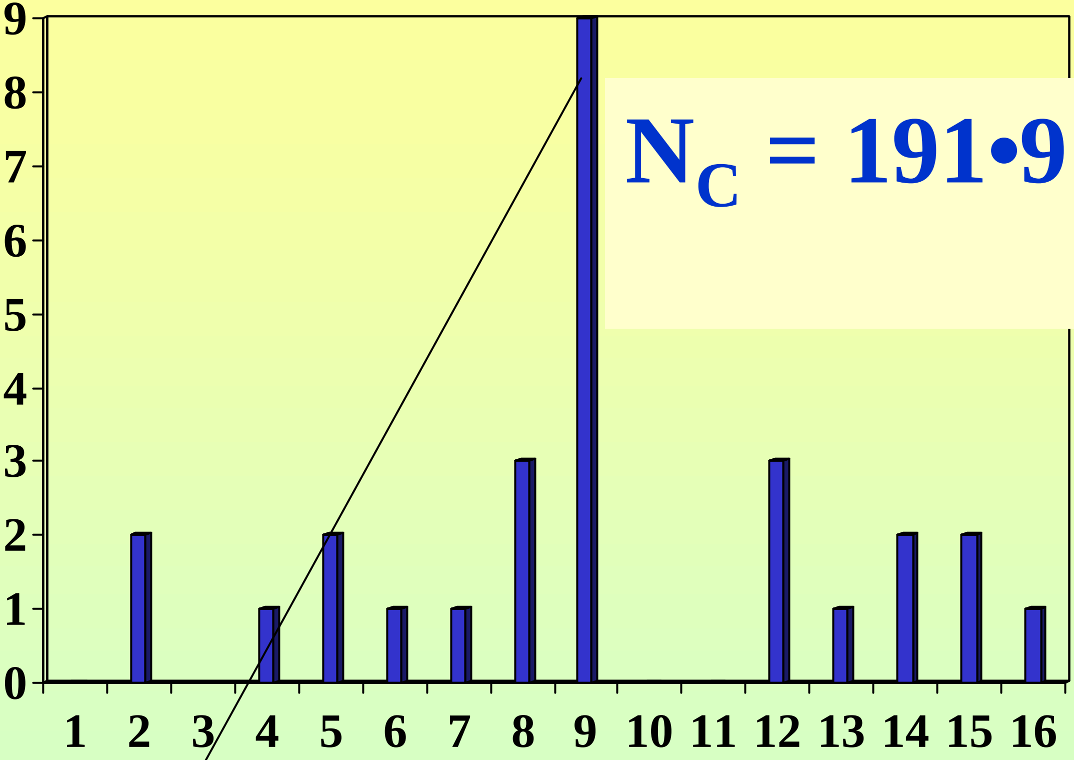
A correlation analysis was performed using all the experimental data, and correcting Kamioka and Baksan time (±1 min) with IMB timing.

DETECTED NEUTRINO SIGNALS

Mont Blanc	5 pulses		$E \geq 5$ MeV	UT 2:52:36.8 ± 2 ms
Kamioka	11	“	8	7:35:35 ± 1 min
MB	8	“	25	7:35:41 ± 5 ms
BST	(2+5)	“	10	2:52:34 and 7:36:06 (+ 2s-54s)

The main signal comes from electron antineutrinos: $\bar{\nu}_e p$ — $n e^+$ followed by $e^+ e^-$ annihilation producing 2 γ’s, detectable in scintillator but not in water. The Mont Blanc signal ($5.8 \leq E_{vis} \leq 7.8$ MeV) corresponds to $4.6 \leq E_{vis} \leq 6.6$ MeV in water, at the limit to be detected in Kamioka.

Coincidences Mt.Blanc-Kamiok



$$N_C = 191 \cdot 91 \cdot 2 \cdot 0.5/7200 = 2.$$

$$N_O = 9$$

Mt. Blanc event time
1:45 – 3.45 U.T.

Coincidence window: $\Delta t = \underline{+}\ 0.5$ s

Bin width: 2 hours

Coincidence time: 34 hours

Kamioka time + 7 seconds

WHAT HAVE WE LEARNED FROM SN 1987A?

•**Neutrinos:** One or two bursts? Feb. 23.12 and/or Feb 23.32 or a long activity during the ~ 2 hours of coincidence time? Was that a 2 steps collapse, first into a NS and 4.7 hours late into a BH or a SQM star? **More statistics is needed!!!**

•**Light:** A week after the explosion $m_V = 4.5$ and $M_V = -14.5$ being 18.5 the distance module, and $A_V = 0.45$. Hence this SN wouldn’t be visible by naked eye if exploded in the disk of our Galaxy, unless closer than ~ 5 kpc (assuming an extinction parameter of ~ 1.5 mag/kpc). However the neutrino burst would have been **100 times stronger!!!**

•**Hidden sources:** Are there sources visible only in neutrino and not light? Is the rate of collapses higher than that of SN?