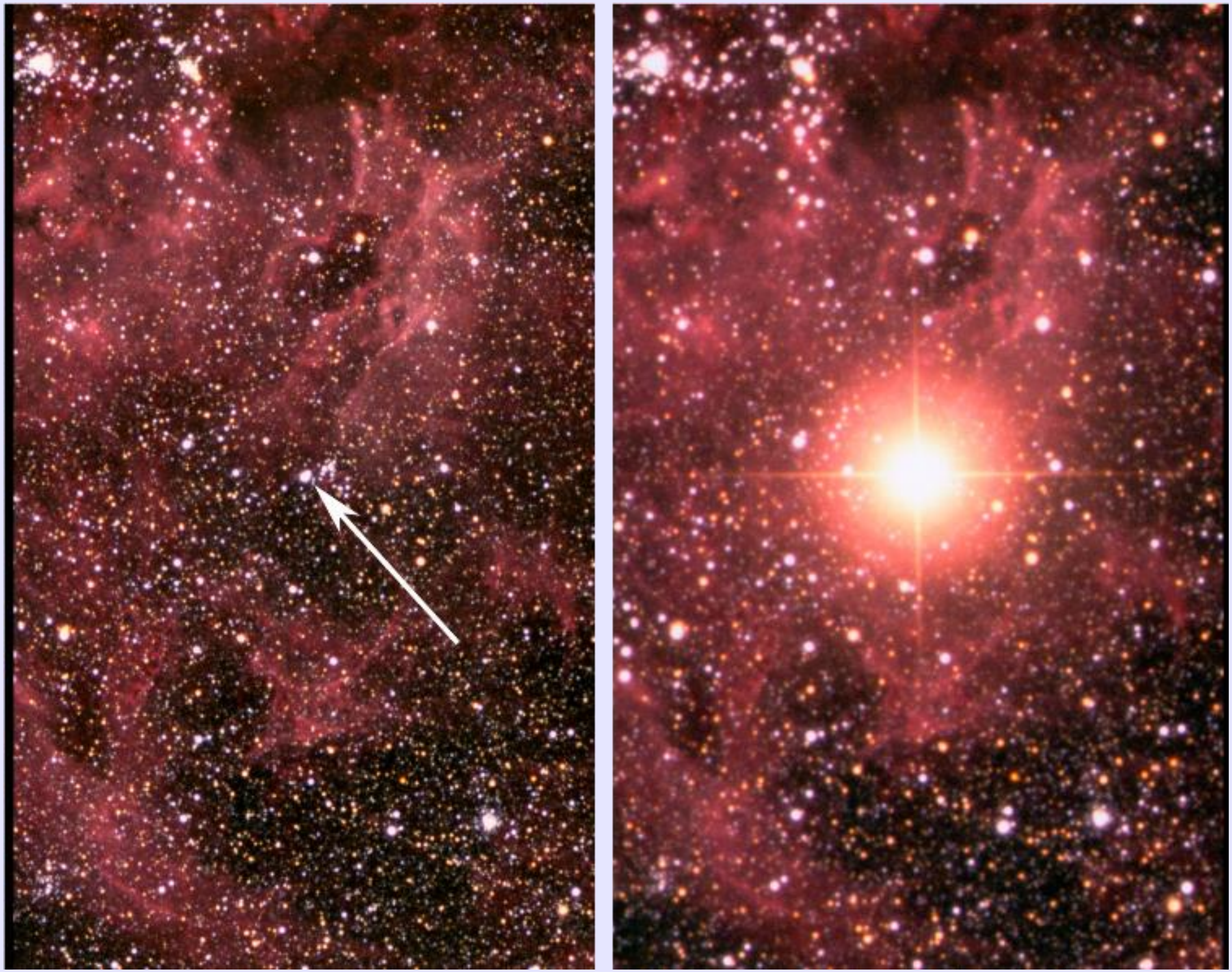
Revisiting the Mont Blanc Early Neutrino Burst from Supernova 1987A



At about 7:35 UT on Feb 23, 1987

3 neutrino detectors recorded 23 events
within $\pm$ 1 minute

All were hydrogenous detectors:

IMB	water Cerenkov	20 MeV threshold
Kamioka	water Cerenkov	6 MeV threshold
Baksan	scintillation	10 MeV threshold

all primarily sensitive to $\bar{\nu}_e$ via inverse beta decay $\bar{\nu}_e + p \rightarrow e^+ + n$

Kamioka, Baksan, IMB observe clusters of events on Feb 23, 1987 about 7:35 UT
NOTE LARGE TIMING UNCERTAINTIELS ~1 min. IN KAMIOKA, BAKSAN

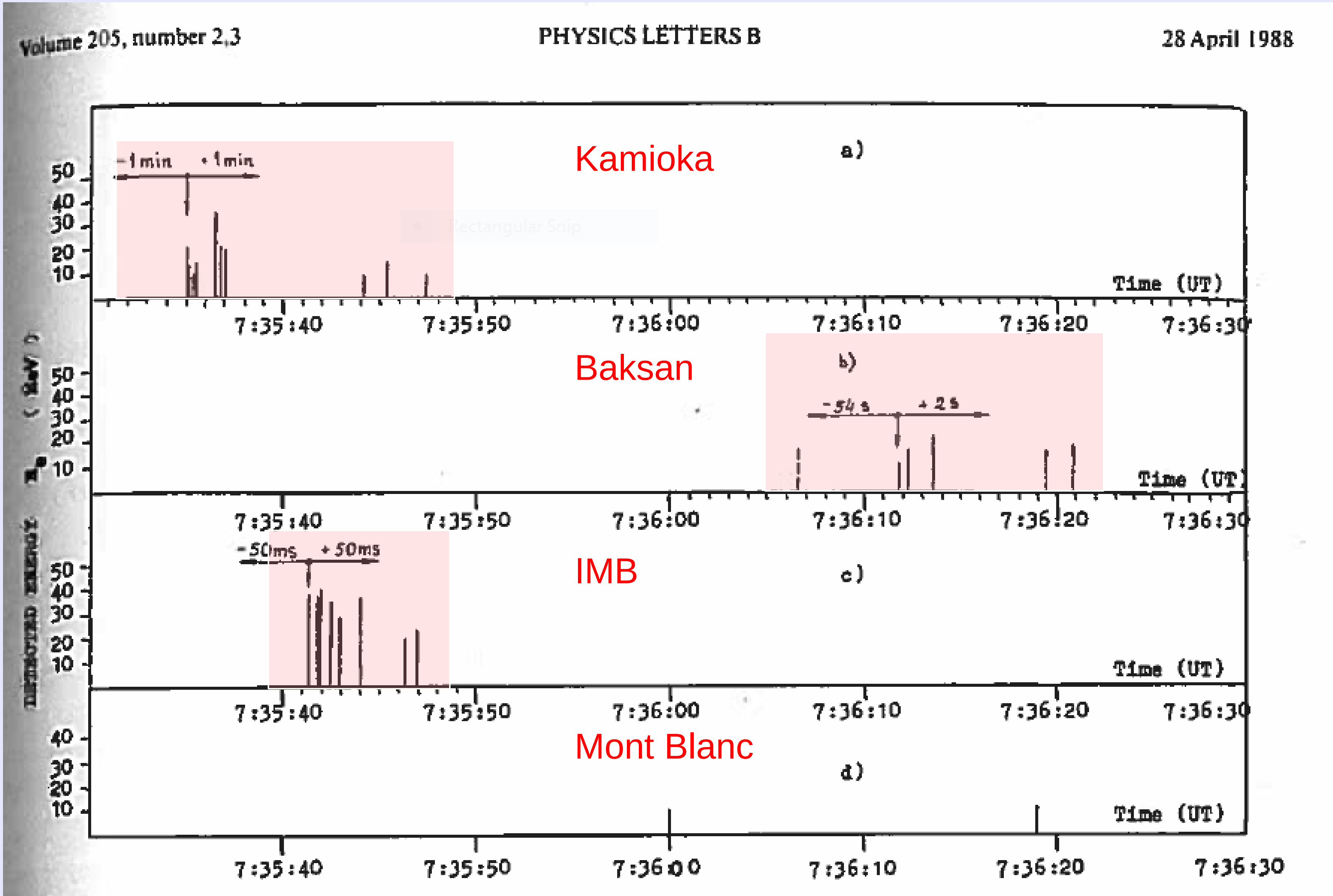
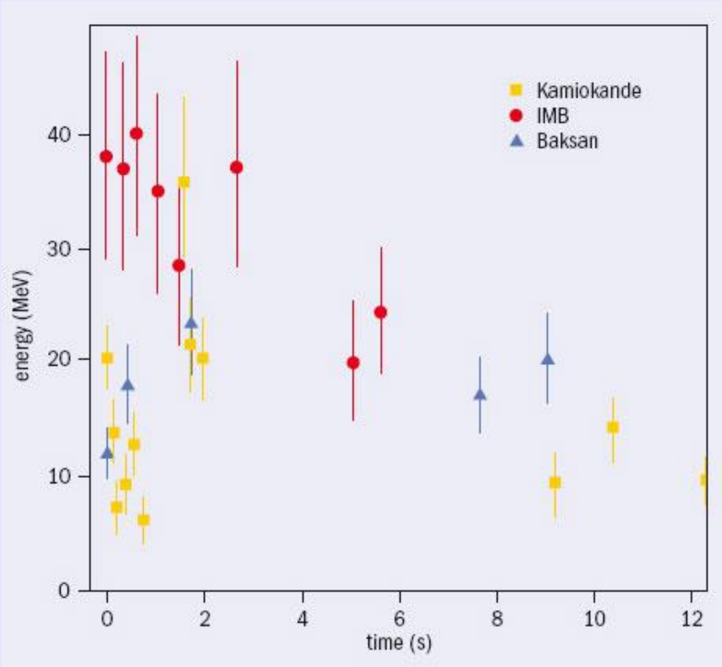
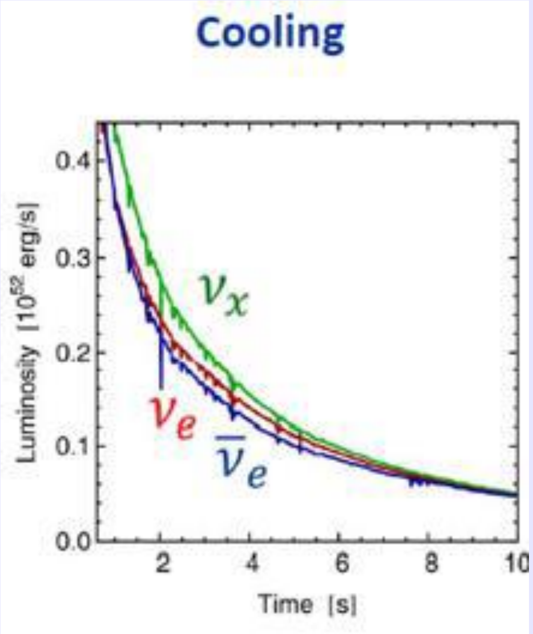


Fig. 2. The time sequences of events detected by KAMIOKANDE-II (a), the Baksan telescope (b), IMB (c) and LSD (d) detectors at 7:35 UT on February 23, 1987.

From Alexeyev et al., Phys. Letters B 205, 1988

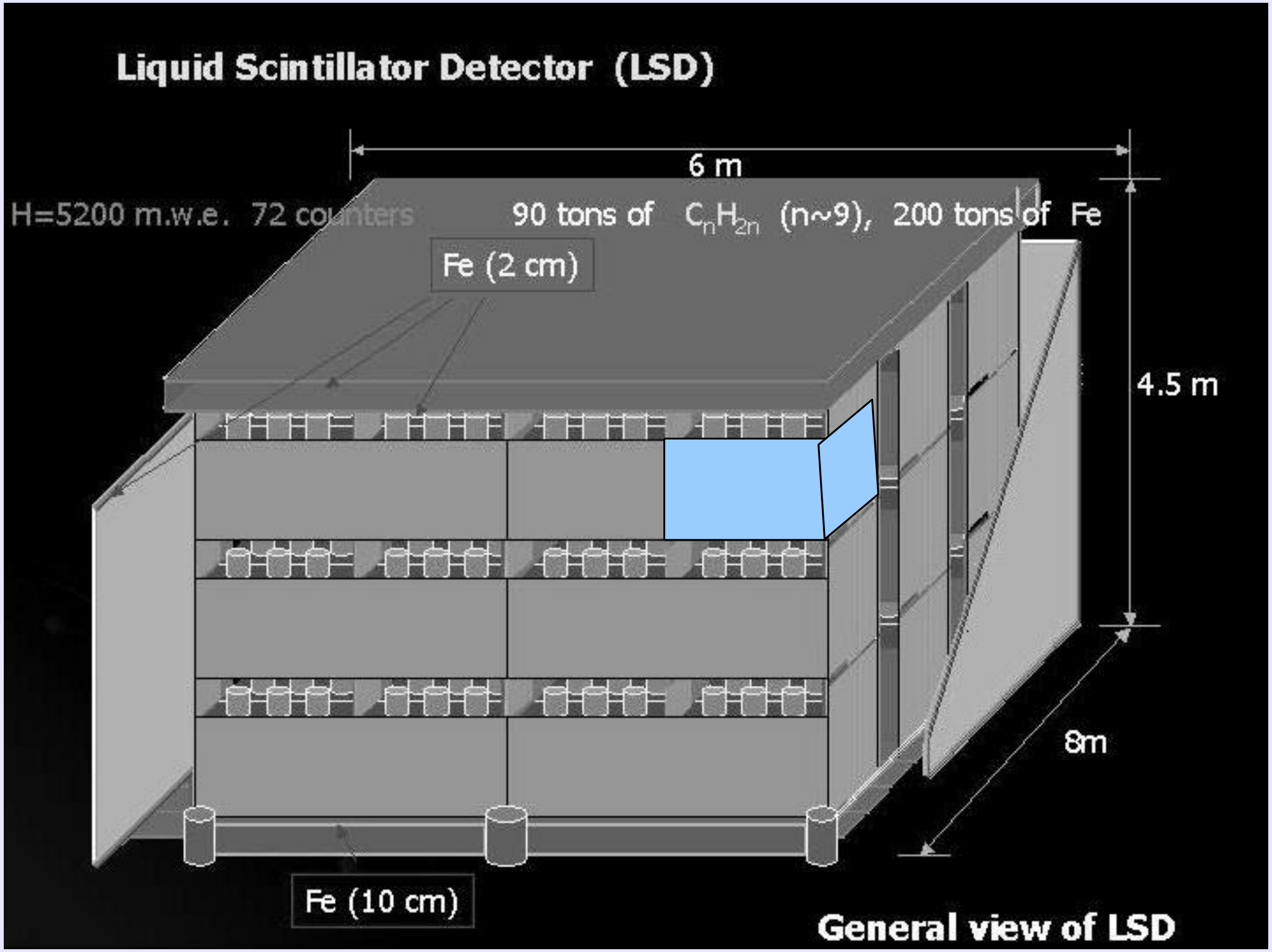




The observed decay time of the neutrino signal of ~10 seconds roughly matches the theoretical expectation of a cooling neutron star.

A fourth detector at Mont Blanc 90 tons liquid scintillator (= 4% of Kamioka)
200 tons of iron
threshold 5-7 MeV

did not record a signal in coincidence with the other 3 detectors



But Mont Blanc alone observes a cluster of 5 events about 4.7 hours <u>earlier</u>;
no clusters observed in the other detectors.

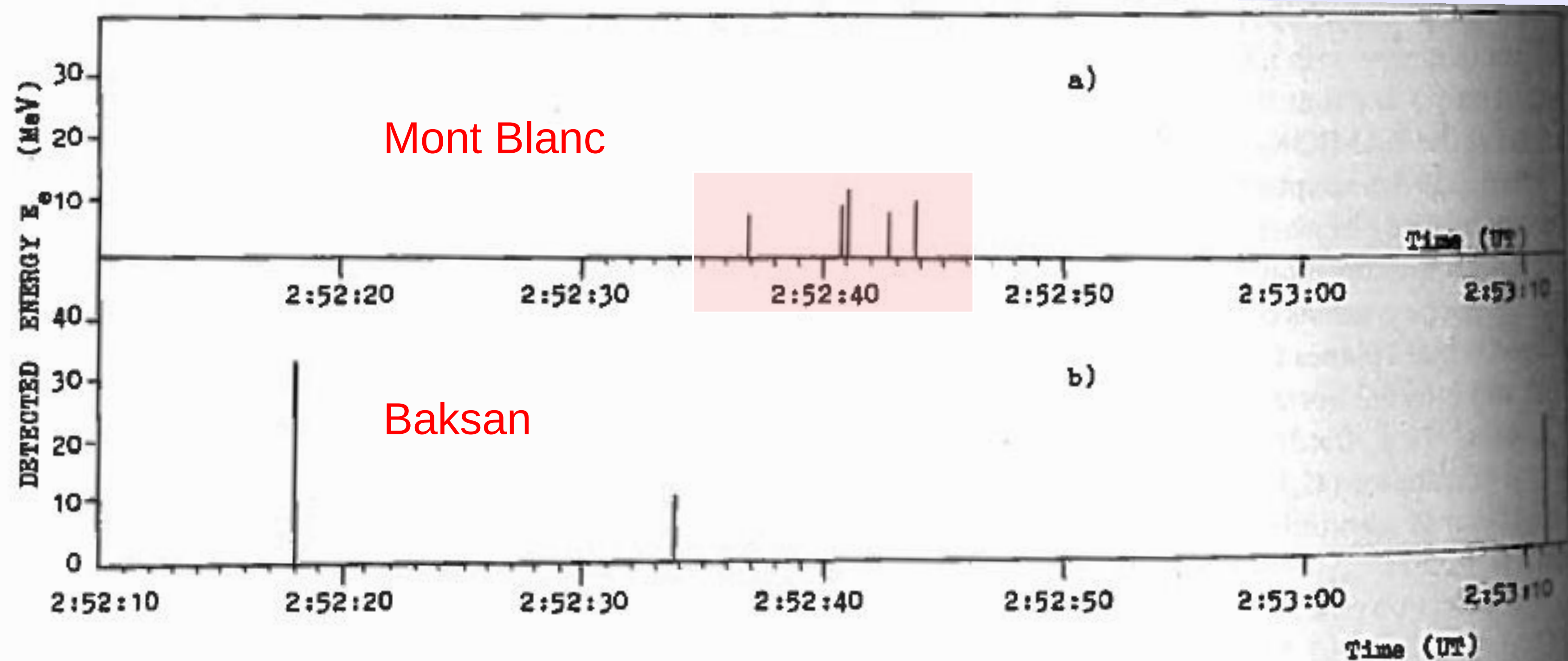


Fig. 1. The time sequences of events detected by the LSD (a) and the Baksan telescope (b) at 2:52 UT on February 23, 1987.

If this signal is real, it must be due to the unique presence of iron in this detector.

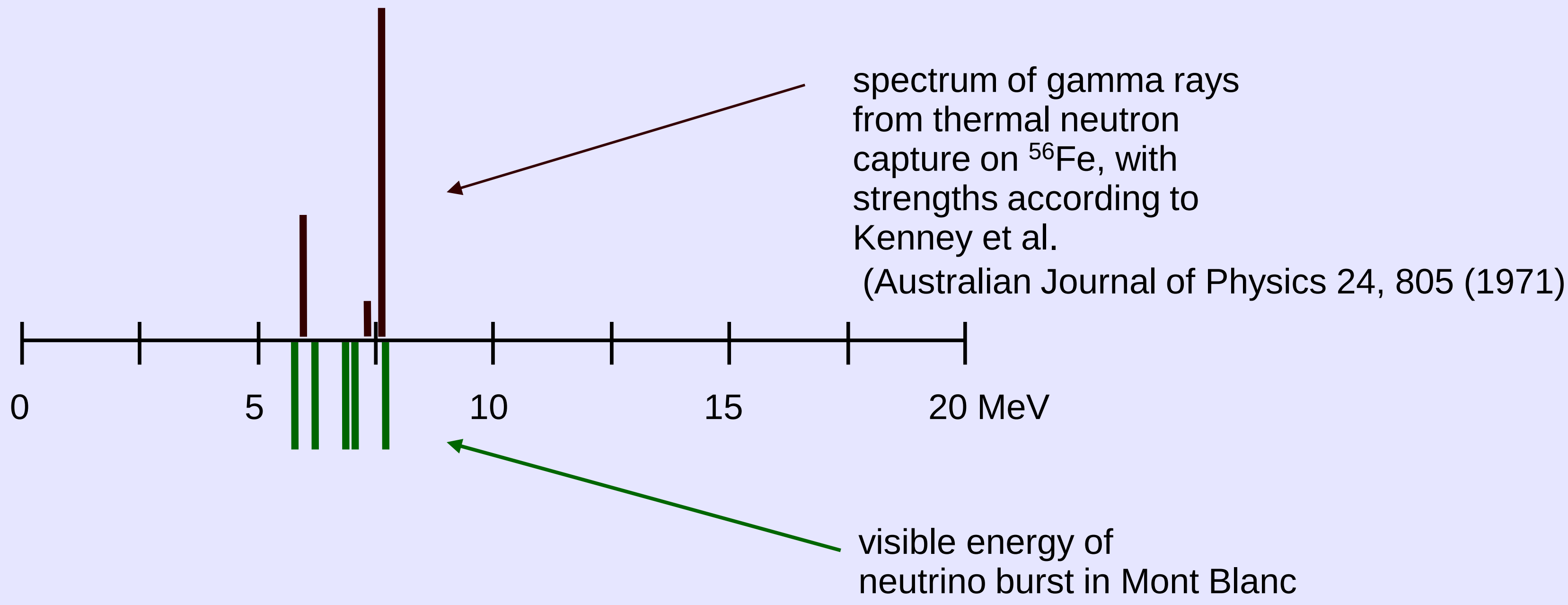
Table I - Characteristics of the pulses in the burst detected on February 23rd, 1987

Event no.	Counter no.	Time (UT)	E_{vis} (MeV)
994	31	$2^h 52^m 36^s.79$	6.2
995	14	40.65	5.8
996	25	41.01	7.8
997	35	42.70	7.0
998	33	43.80	6.8

The visible energy in the liquid scintillator was tightly clustered around ~ 7 MeV, which defied satisfactory explanation.

It must have something to do with neutrino-induced interactions with iron …

Neutron capture on ^{56}Fe ?



Voilà ! **It fits like a hand in a glove !**

It seems highly plausible that the signal in the Mont Blanc detector was due to capture of thermal neutrons on the iron slabs surrounding the liquid scintillator.

Suppose that there were a source of very low energy neutrons in the various detectors.
How much visible energy would be seen in the various detectors?

In Mont Blanc:

energy liberated in $^{56}Fe + n \rightarrow {}^{57}Fe + \gamma$ 7.64 MeV [for zero-energy neutrons]
above threshold of Mt Blanc detector
VISIBLE

This is close to the visible energies of the 5 events observed at Mt Blanc !!

In the hydrogenous detectors (IMB, Kamioka, Baksan)

energy liberated in $n + p \rightarrow d + \gamma$ 2.22 MeV below threshold of Mt Blanc
and the other 3 detectors
INVISIBLE

The iron slabs act like an amplifier for low-energy neutrons -- even a thermal neutron of energy of 0.025 eV can make 7.64 of visible (electromagnetic) energy in the scintillator tanks of the Mont Blanc detector

My hypothesis:

An early burst of low energy $\bar{\nu}_e$ (1.8 < E < 6 MeV) which make low energy neutrons via inverse beta decay on protons in the liquid scintillator

$\bar{\nu}_e + p \rightarrow e^+ + n$ (energy threshold = 1.8 MeV)

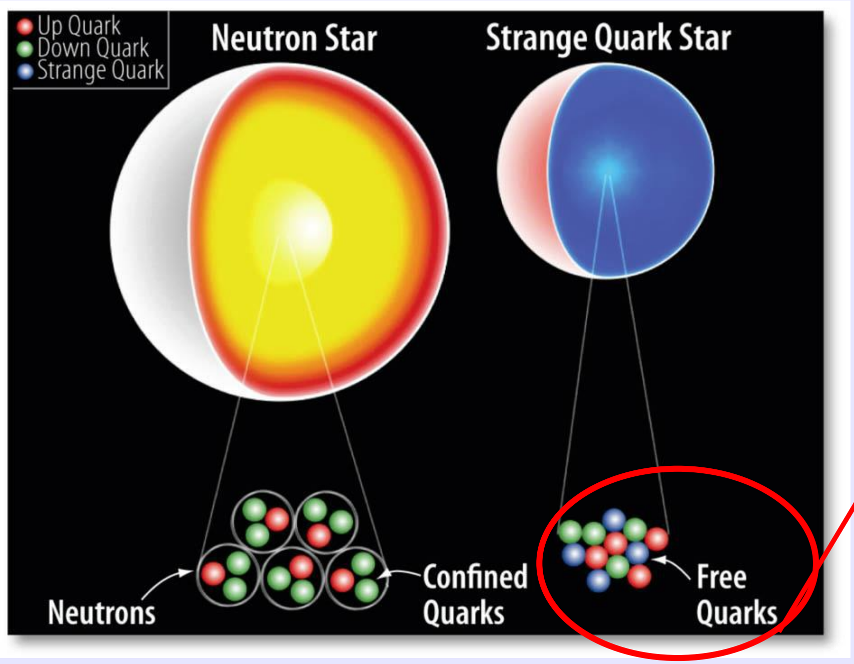
These neutrons then capture on the iron slabs and make the
5-7 MeV of visible energy in the Mt Blanc detector,
but make no signal in the hydrogenous detectors because they all
have thresholds ≥ 6 MeV.

That's the formation of the neutron star?

4.7 Hours later…

A late burst of much higher energy (10-40 MeV) neutrinos are seen in other 3 detectors, but not seen in Mt Blanc because of its small mass.

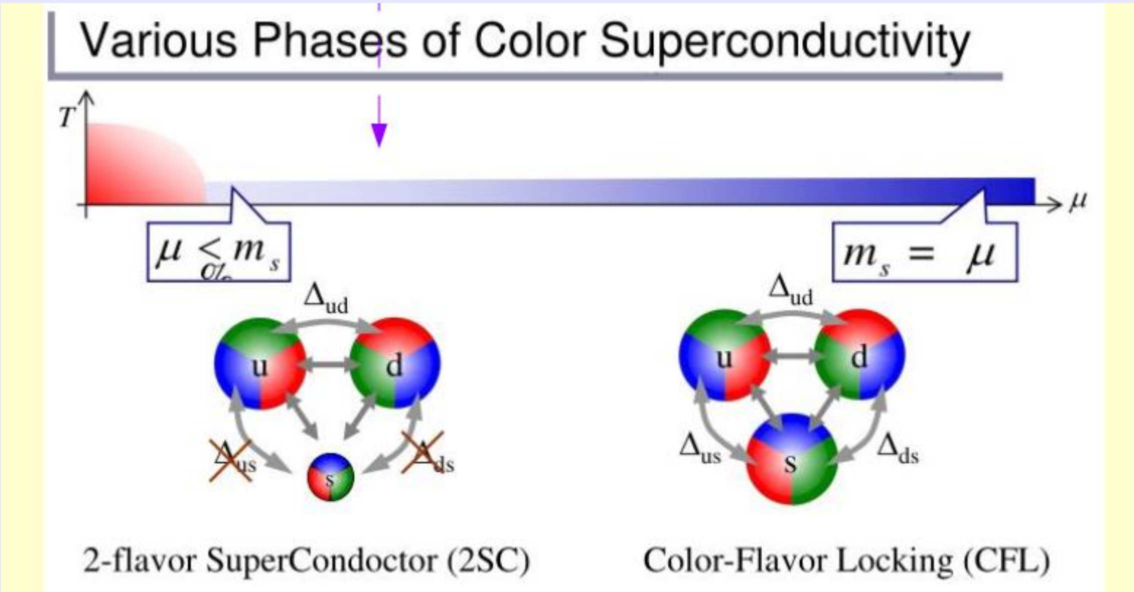
That's the QCD phase transition to color-superconducting quark matter?



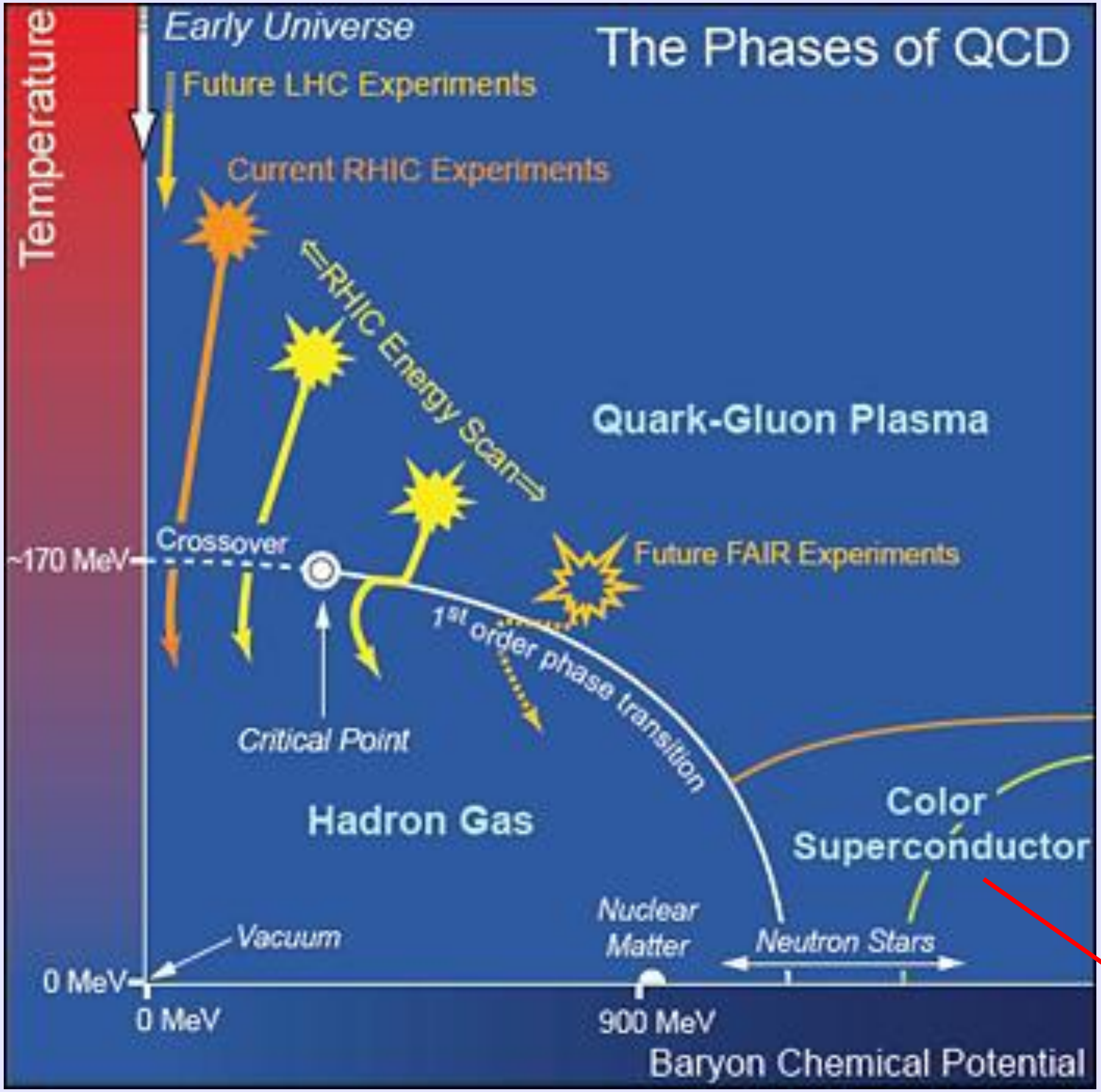
From Universe Today, June 30, 2008

“Color superconductivity

- Quarks form “Cooper Pairs” in either 2-flavor (ud) or 3-flavor (uds) space



PPT - 北沢 正清 大阪大学 PowerPoint Presentation



https://arxiv.org/pdf/1501.06477.pdf

This represents the low temperature, high density region of the QCD phase diagram which can be attained nowhere else except in compact stars; maybe seen for the first time in SN1987A.