Detector systems
for satellite and balloon experiments

Osaka University
NOMACHI, Masaharu

能町正治
NOMACHI MASAHARU

PhD in nuclear physics

PostDoc in Heidelberg
experiment in CERN

In KEK, Japan
Working on Data Acquisition

Research Center for Nuclear Physics (RCNP) of Osaka University

A Joint Usage/Research Center with an aim to promote international collaborations on cutting-edge research in nuclear physics as well as applied sciences, by making the most of the uniqueness in having the largest facility on a university campus.

The RCNP accelerator facility is equipped with a cyclotron cascade consisting of two variable-energy multi-particle cyclotrons;
- a K140 AVF cyclotron constructed in 1973,
- a K400 ring cyclotron constructed in 1991.

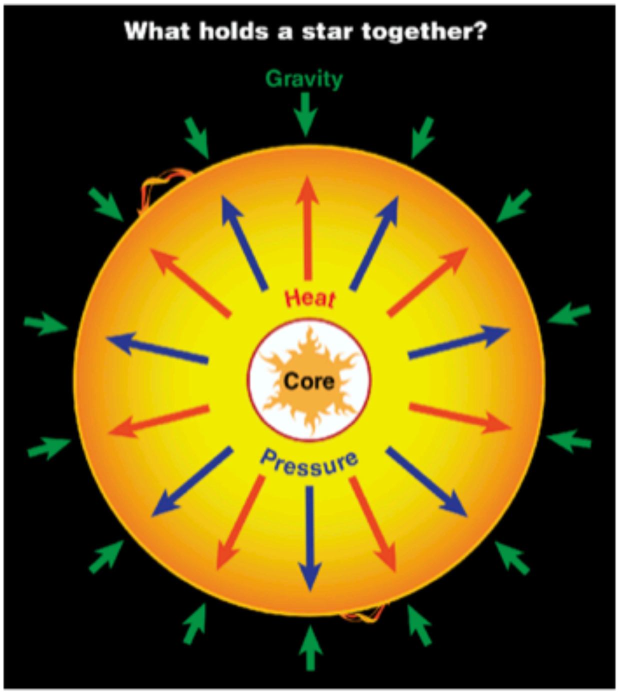
The maximum acceleration energy of the ring cyclotron is 420 MeV for protons and 100 MeV/nucleon for heavy ions.

A variety of ion beams are utilized for the research in nuclear physics, radio chemistry and interdisciplinary research field.

The AVF cyclotron is mainly used as an injector of the ring cyclotron, and regularly operated for production of radio-isotopes in a stand-alone mode.

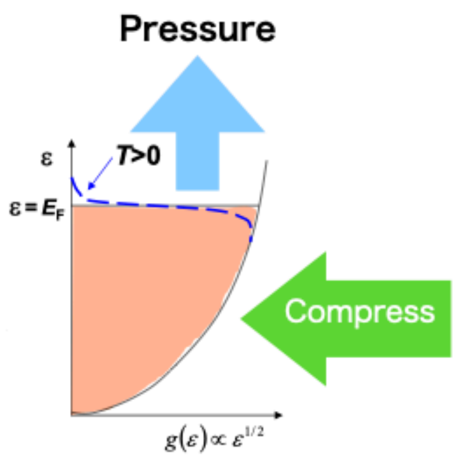
SN1987A

Large Magellanic Cloud



https://spaceplace.nasa.gov/supernova/en/

Electron degeneracy pressure holds a star together.



http://www.physics.rutgers.edu/~gersh/351/Lecture%2024.pdf

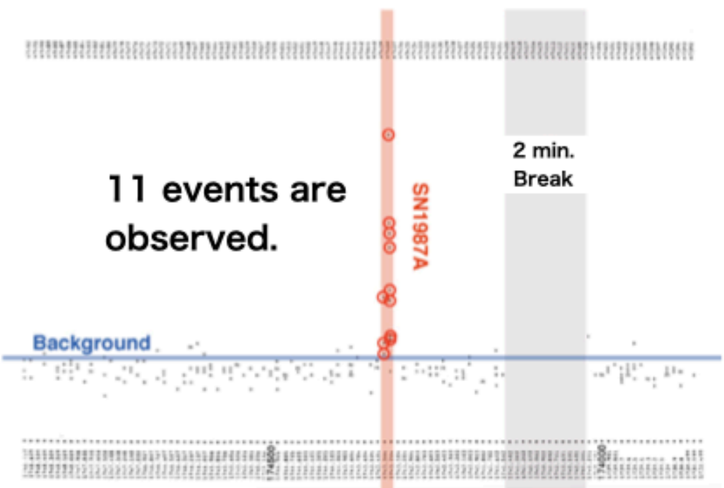
Electron is Fermion.
Two Electrons cannot occupy the same state

Gravitational collapse

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

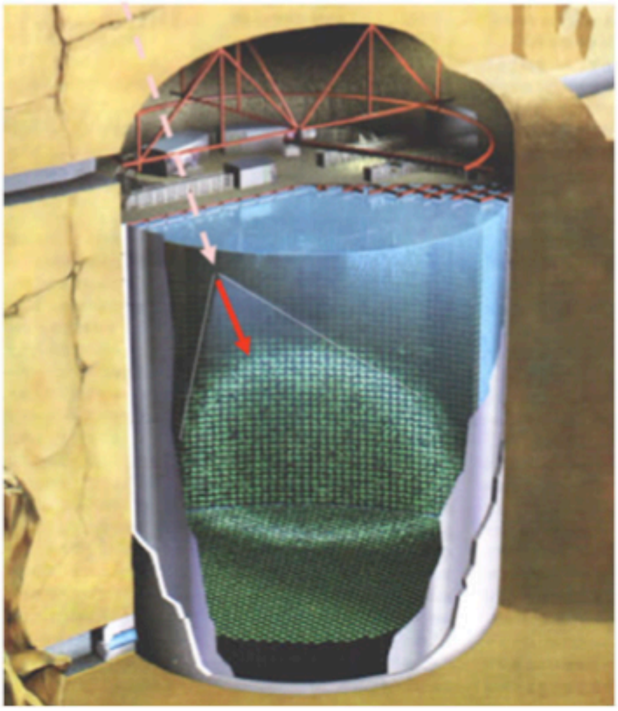
Disappearance of Electrons causes Loss of Electron degeneracy pressure

Collapsed matter bounces, then explodes.



Neutrino detector

Neutrino interaction causes energetic electron.
The electron causes Cherenkov photons.



(c) Kamioka Observatory, ICRR(Institute for Cosmic Ray Research), The University of Tokyo

The Nobel Prize in Physics 2002

Photo from the Nobel Foundation archive.
Raymond Davis Jr.
Prize share: 1/4

Photo from the Nobel Foundation archive.
Masatoshi Koshiba
Prize share: 1/4

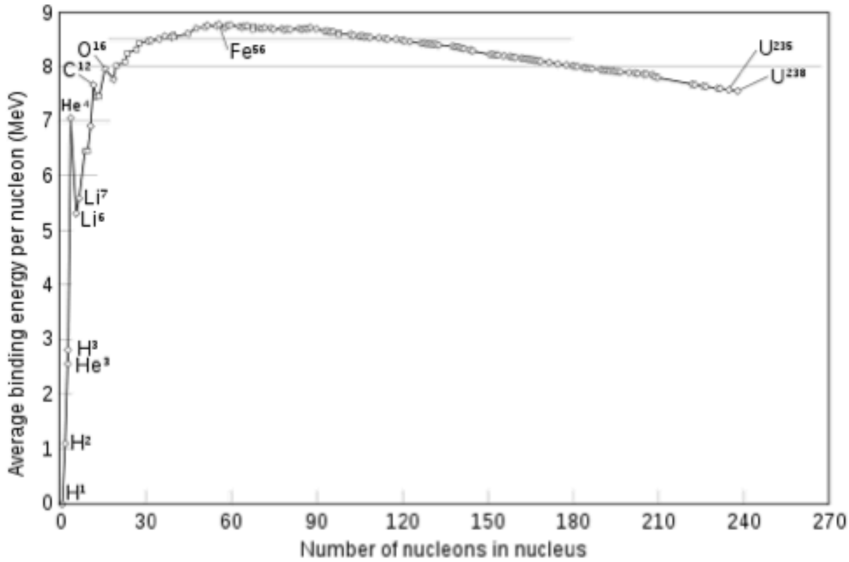
Photo from the Nobel Foundation archive.
Riccardo Giacconi
Prize share: 1/2

The Nobel Prize in Physics 2002 was divided, one half jointly to Raymond Davis Jr. and Masatoshi Koshiba "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos" and the other half to Riccardo Giacconi "for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources."

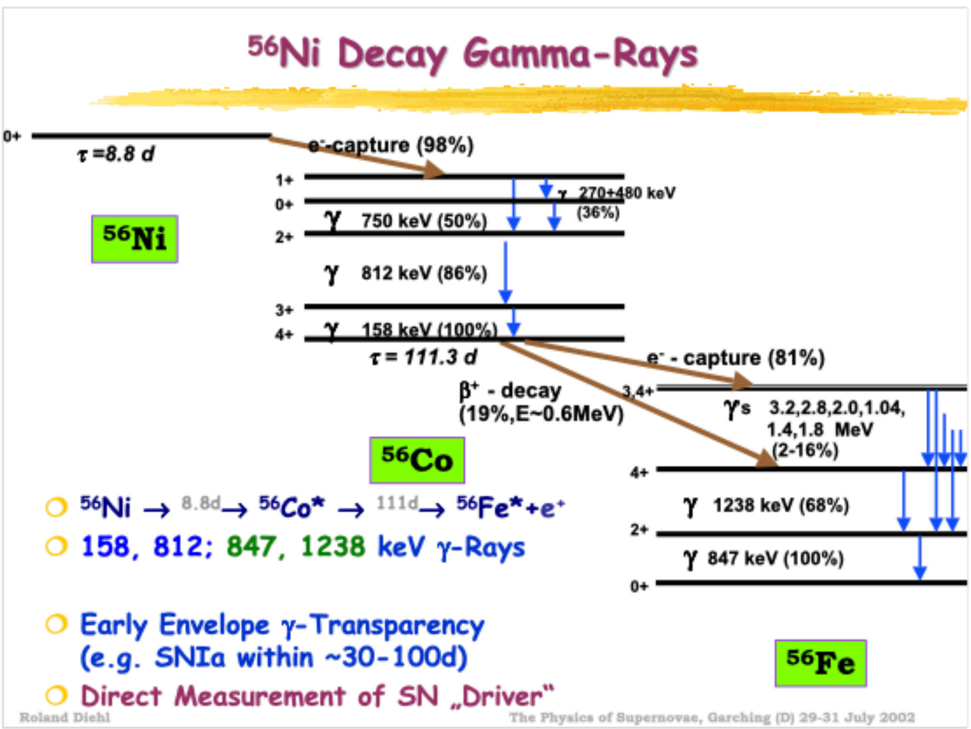
https://www.nobelprize.org/prizes/physics/2002/summary/

Silicon-burning process at the last moment

$$^{28}_{14}\mathrm{Si} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{32}_{16}\mathrm{S}$$
$$^{32}_{16}\mathrm{S} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{36}_{18}\mathrm{Ar}$$
$$^{36}_{18}\mathrm{Ar} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{40}_{20}\mathrm{Ca}$$
$$^{40}_{20}\mathrm{Ca} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{44}_{22}\mathrm{Ti}$$
$$^{44}_{22}\mathrm{Ti} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{48}_{24}\mathrm{Cr}$$
$$^{48}_{24}\mathrm{Cr} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{52}_{26}\mathrm{Fe}$$
$$^{52}_{26}\mathrm{Fe} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{56}_{28}\mathrm{Ni}$$
$$^{56}_{28}\mathrm{Ni} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{60}_{30}\mathrm{Zn}$$

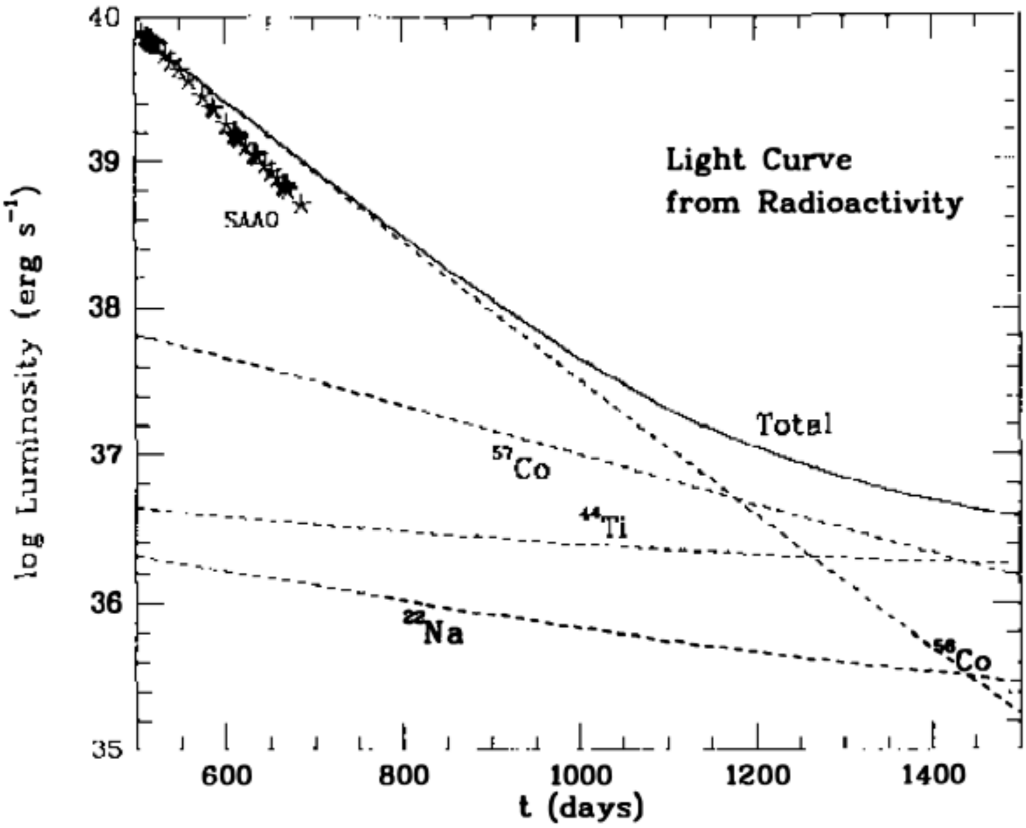


https://en.wikipedia.org/wiki/Silicon-burning_process



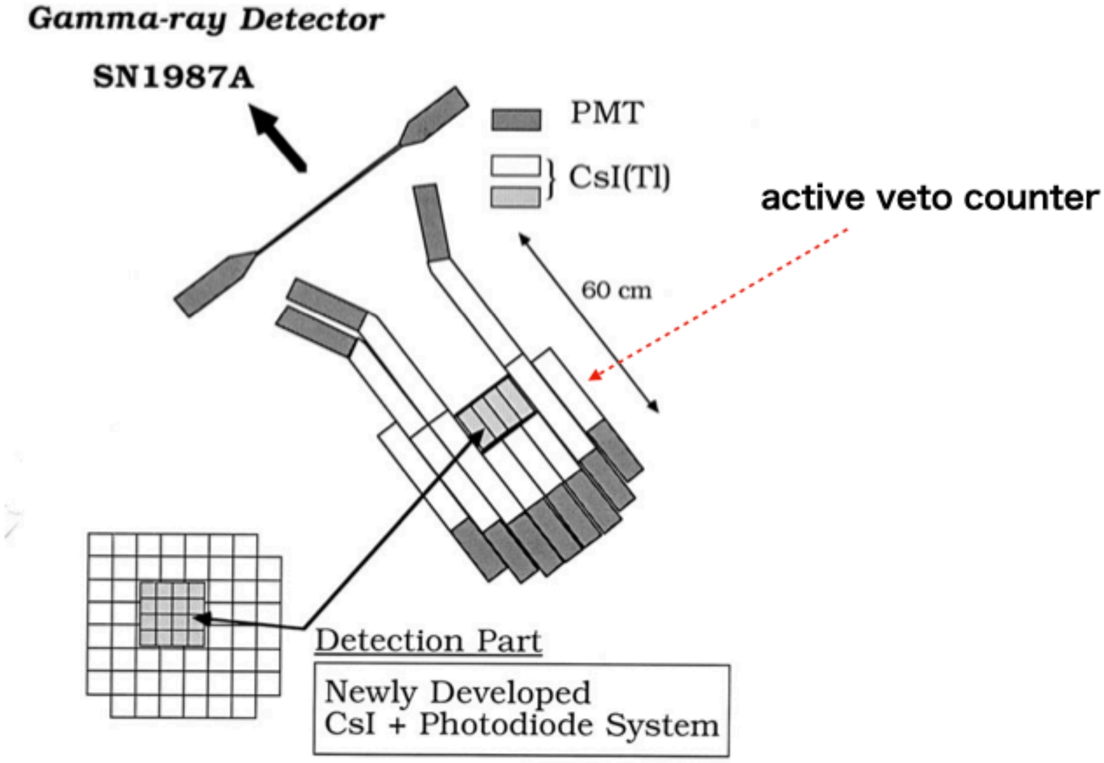
https://www.mpe.mpg.de/~rod/SN_talk_RDiehl.pdf

Annu. Rev. Astron. Astrophys. 1989. 27: 629–700



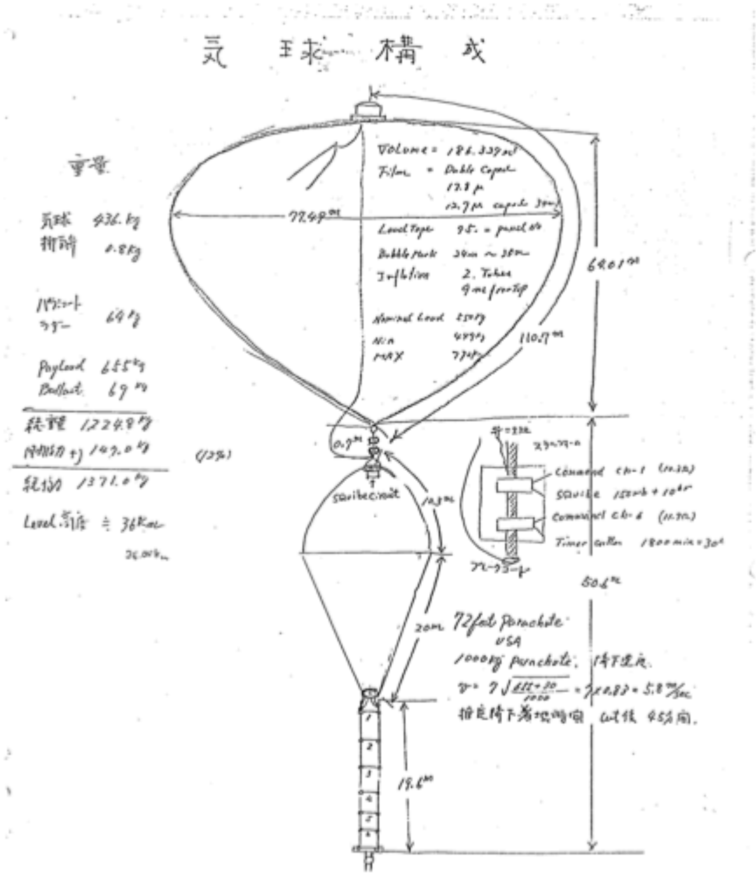
(a)

Go to Brazil

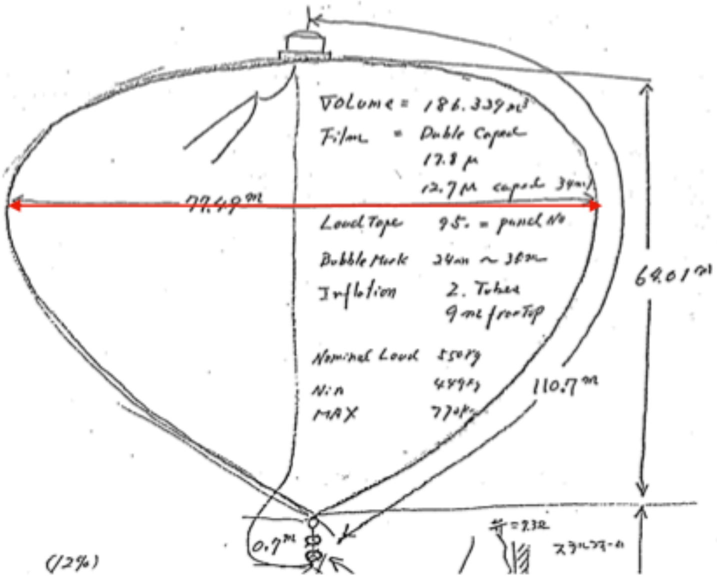


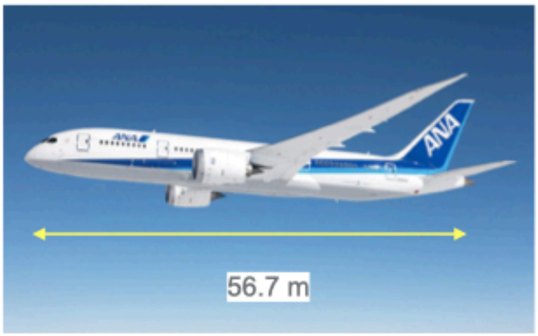
Opening Angle ±12° (FWHM at 1 MeV)

Total Weight ≈550 kg (Detector Part)



Observation at 35km
(stratosphere)





https://www.ana.co.jp/ja/jp/domestic/departure/inflight/seatmap/

Going up In troposphere (0 ~ 11km)
pressure and temperature go down by Adiabatic expansion.

Balloon also does Adiabatic expansion.
Therefore, the buoyancy is almost constant.
=> Balloon cannot keep hight / unstable

At stratosphere, temperature go up.
=> Stable hight can exist.

A limit on the Co-57 gamma-ray flux from SN 1987A

• September 1992 The Astrophysical Journal 397(2):L83-L86
DOI: 10.1086/186550

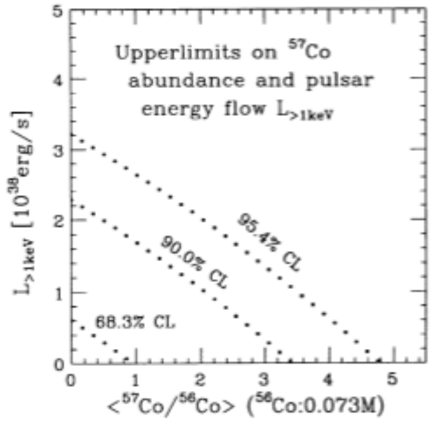
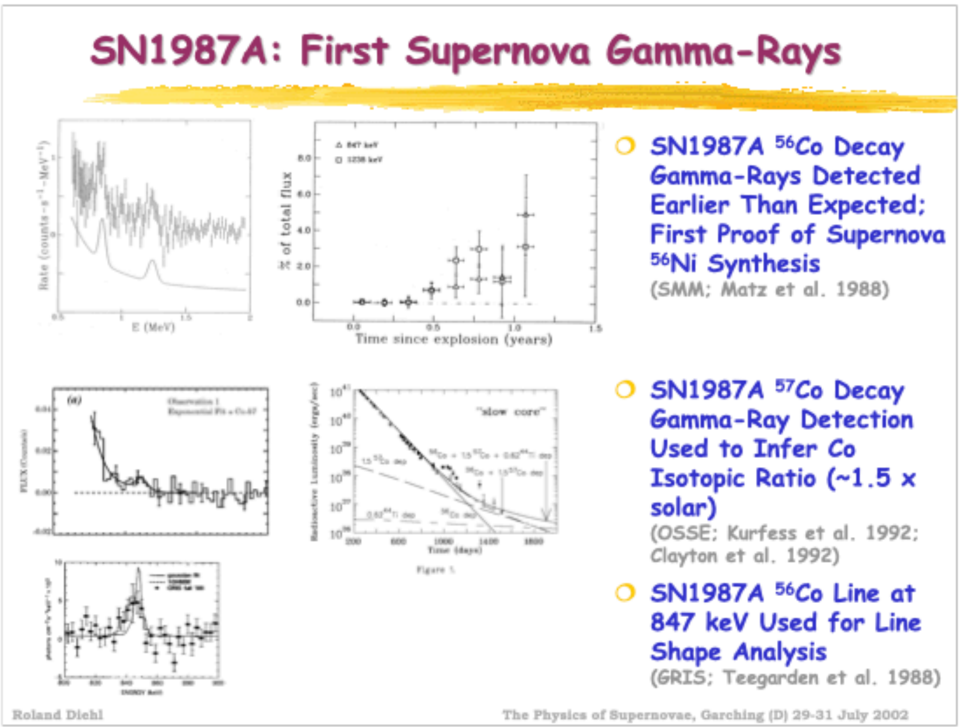


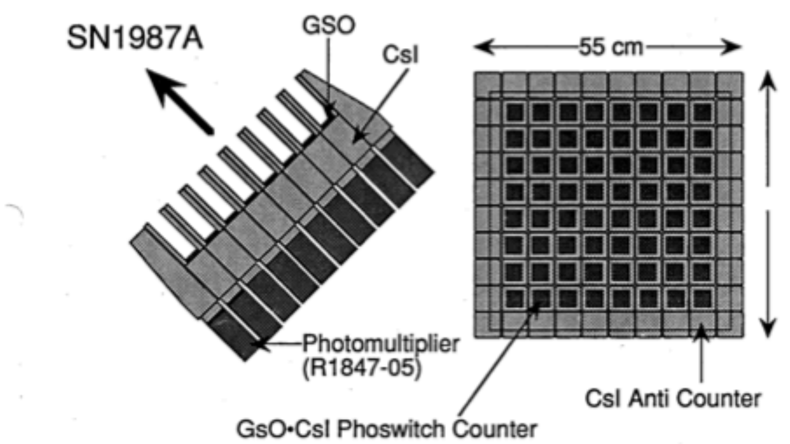
FIG. 4.—Upper limits at 68.3%, 90.0%, and 95.4% CL for the ^{57}Co abundance and the pulsar energy outflow.

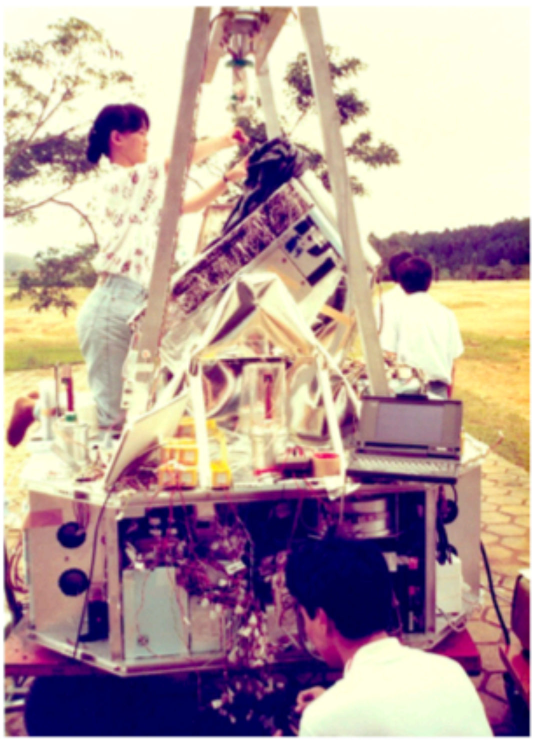


https://www.mpe.mpg.de/~rod/SN_talk_RDiehl.pdf

Back to Brazil

WELCOME-1 TELESCOPE

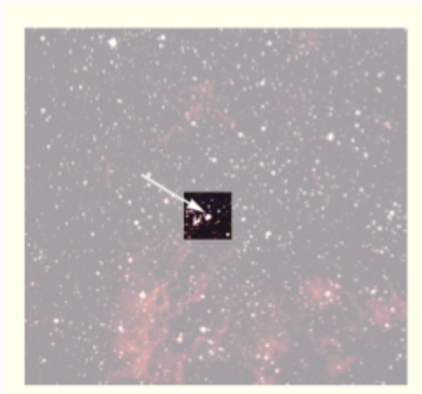




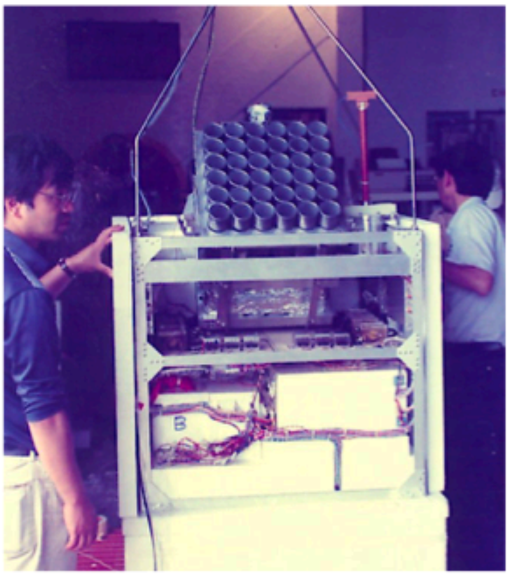
How to improve the sensitivity.

Collect more signal
Avoid noise/background

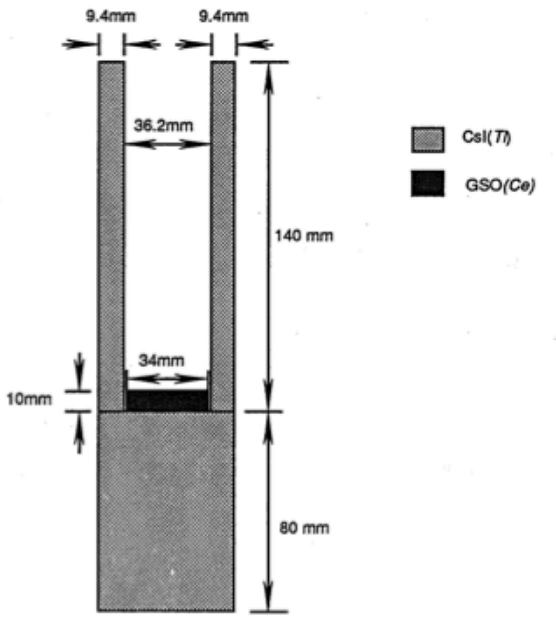
Better S/N ratio **Collimator**



Passive Collimator



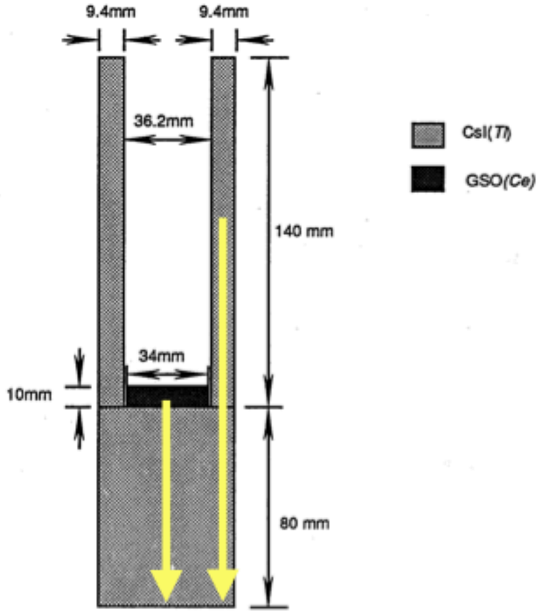
Active Collimator



Detector is surrounded by veto detector
Compton scattering is suppressed

Phoswich detector.
Pulse shape discrimination is applied.

No passive material near by.



Pulse shape depends on scintillator.
Distinguish signal/background using the pulse shape

Pulse shape discrimination

H. Murakami *et al.*, "A simple pulse shape discrimination method for the phoswich counter," in *IEEE Transactions on Nuclear Science*, vol. 39, no. 5, pp. 1316-1320, Oct. 1992, doi: 10.1109/23.173198.

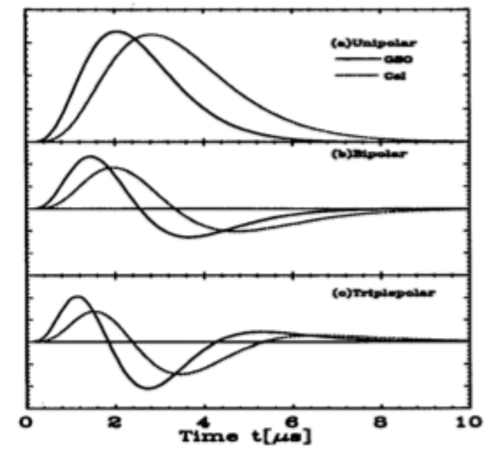


Figure 1: The wave forms of the shaping amplifier with a RC time constant of 500ns: (a)unipolar,(b)bipolar, and (c)triplepolar pulse. The GSO signal is shown by the solid line and the CsI signal by the dotted line.

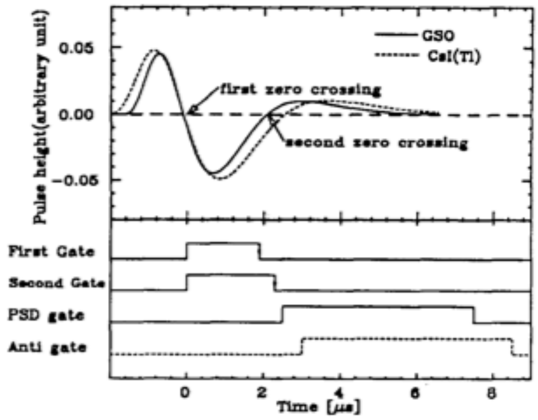


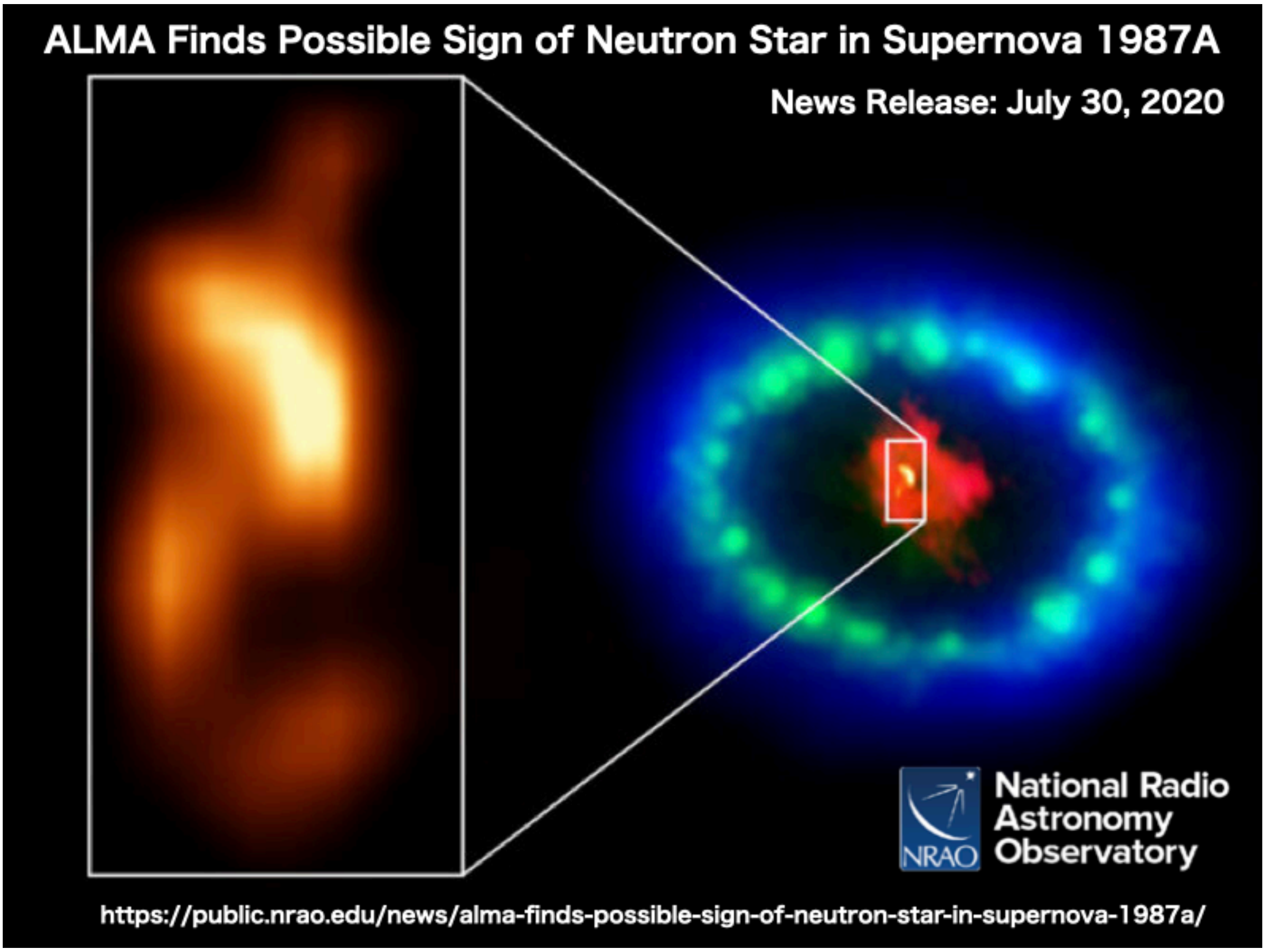
Figure 5: Principle of the pulse shape discriminator. The PSD pulse is issued only if the second zero crossing point falls in the first gate and the second gate.

Evolution of electronics

1987 (33 yeas ago) Analog operation

2020 (today) Digital operation → High speed digitization
Waveform recording

SN1987A today

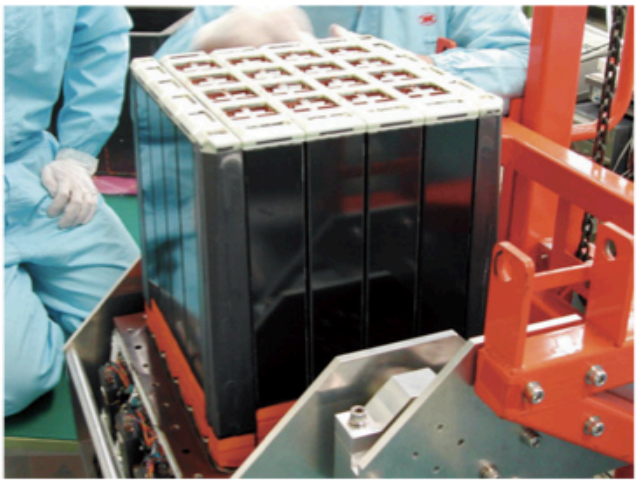


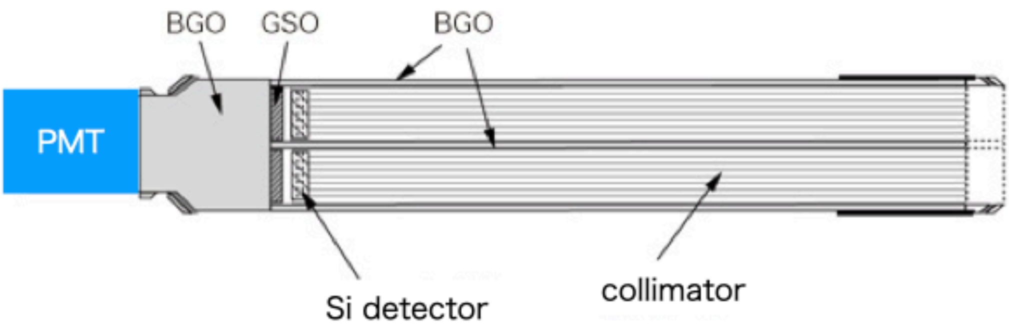
Astro E2 (Suzaku)

Astro H (Hitomi)

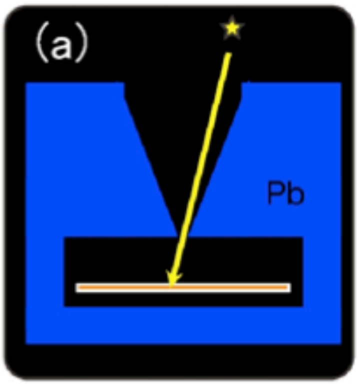
The JAXA Digital Archives

Hard X-ray Detector (HXD)

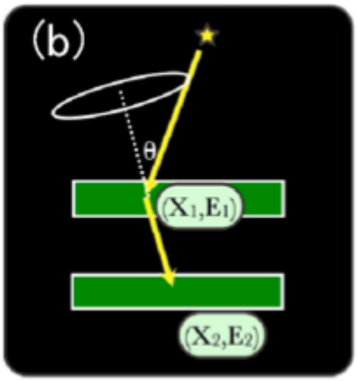




Gamma-rays Camera



(a) Conventional pinhole camera:
It is required to shield gamma-rays other than those coming through the pinhole.



(b) Compton camera principle:
It utilizes Compton scattering of gamma-rays.

What is the difference?

- The space is a vacuum. Almost no air (0.3%) at 35km high.
  - Heat must be removed by conduction.
  - Hard disk nor Magnetic tape do not work.
    - -> Air tight box is required.

- No way to press “reset button”. No way to connect scope for diagnostic.
  - Retry is not possible or takes years
  - Built in diagnostics
  - No test run

- Test before the launch is very important. Therefore, it costs a lot.
  - Simple system is more preferable than high performance.
  - Simple = easy to test.

Thank you

I hope I can have a chance to visit you near future!