KamLAND Experiment

Kamioka Liquid scintillator Anti-Neutrino Detector

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Univ. of Canterbury,

Christchurch, New Zealand

Challenging the ν Mass

Crucial to go physics FAR beyond the SM
Why so small?
Dirac? Majorana?
flavor mixing, ~~CP~~, generation problems,...

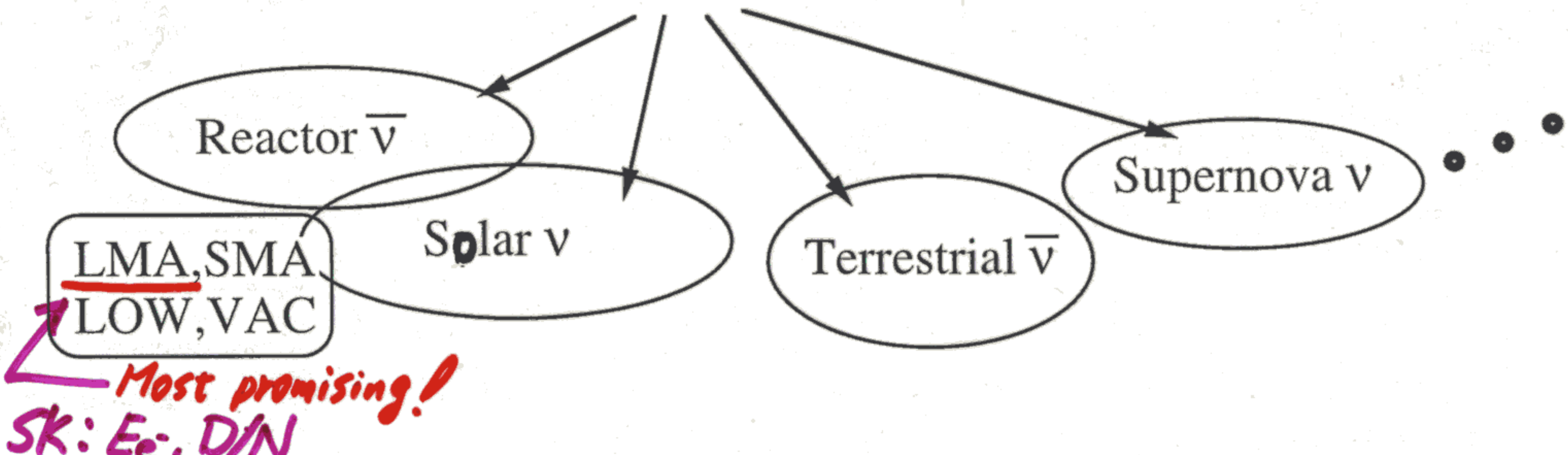
$M_\nu \neq 0$

SuperK atmospheric ν; $\nu_\mu \rightarrow \nu_\tau$

SuperK, SNO; Solar ν; $\nu_e \rightarrow \nu_x$

KamLAND

Real time detection of low energy ν
Using 1000ton liq.Scintillator in
very low background!



KamLAND Collaboration

TOHOKU UNIV.

KEK

Univ. of Alabama

Lawrence Berkeley National Lab.

Univ. of California, Berkeley

California Institute of Technology

Drexel Univ.

Univ. of New Mexico

Triangle Universities Nuclear Lab.

University of Hawaii

Louisiana State Univ.

Stanford Univ.

Univ. of Tennessee

IHEP(China)

14 Institutes from

Japan, US, China

80 collaborators

Site Kamioka mine, underground

1000m rock overburden (2700m w.e.)

Cosmic μ: 0.3Hz (10^{-5}* earth level)

Inner Detector

Liq.Scintillator: 1000ton

(NP(80%)+PC(20%)+PPO(1.5g/l))

light output : 50% of anthracene

High purity: U/Th <10^{-13}g/g, K~10^{-10}g/g

[initial stage]

Balloon: 13mϕ, 135μm(EVOH+Nylon)

Oil layer: 2.5mt, NP+IP

Acryl Plate: 3mmt

PMT: 1325 17"(New) +554 20"(Kam.)

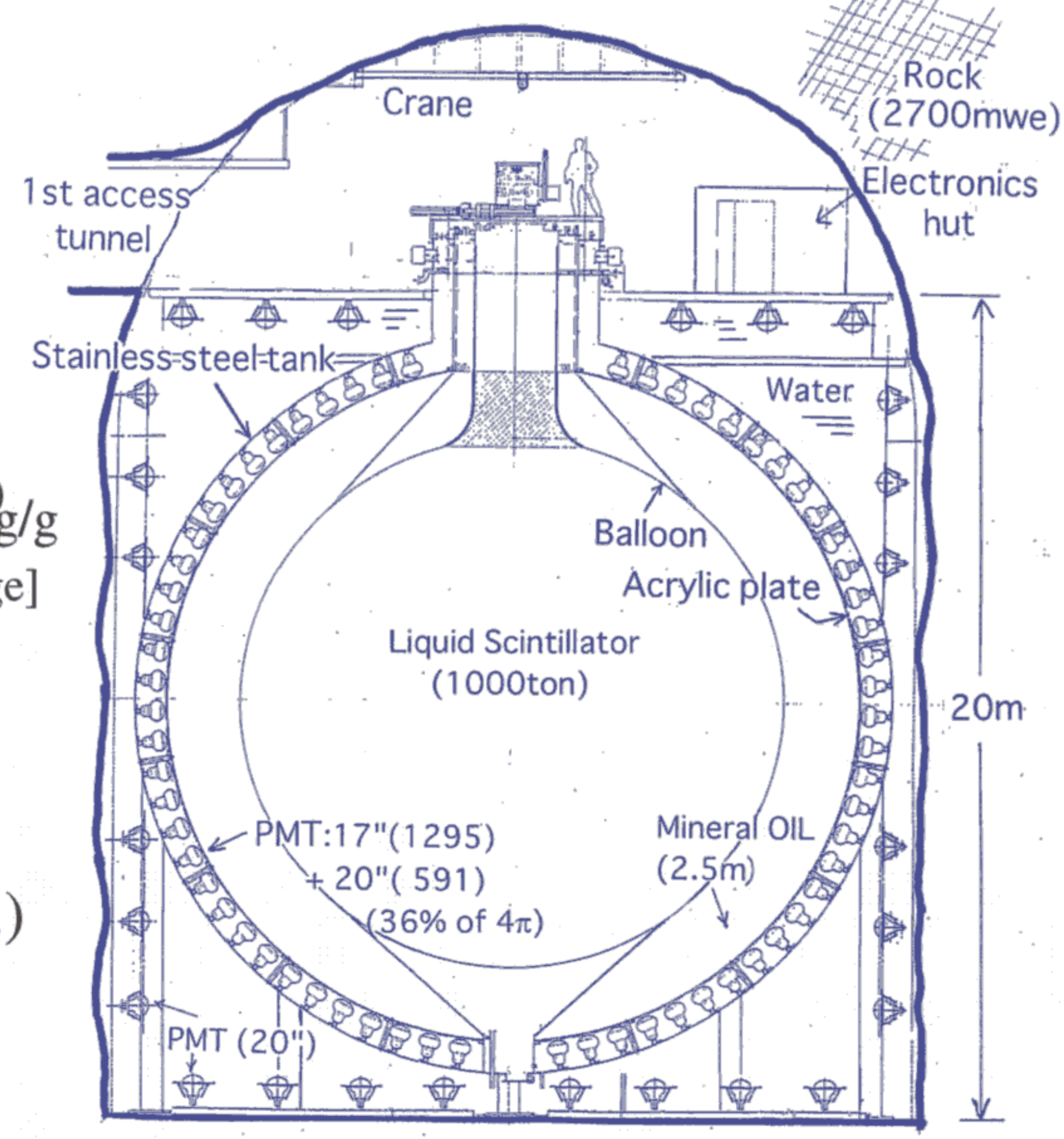
35% of 4π

Spherical tank: 18mϕ, SUS

Outer Detector Water Cherenkov Detector

PMT: 225 20"(Kam.)

KamLAND detector



Reactor Neutrino Experiment

Pure $\overline{\nu}_e$ → No Front detector

$\overline{\nu}_e$ flux & spectrum is well known. → Small systematics ~a few %

Low energy → No μ, τ production (Disappearance exp.) getting larger L/E

Needs

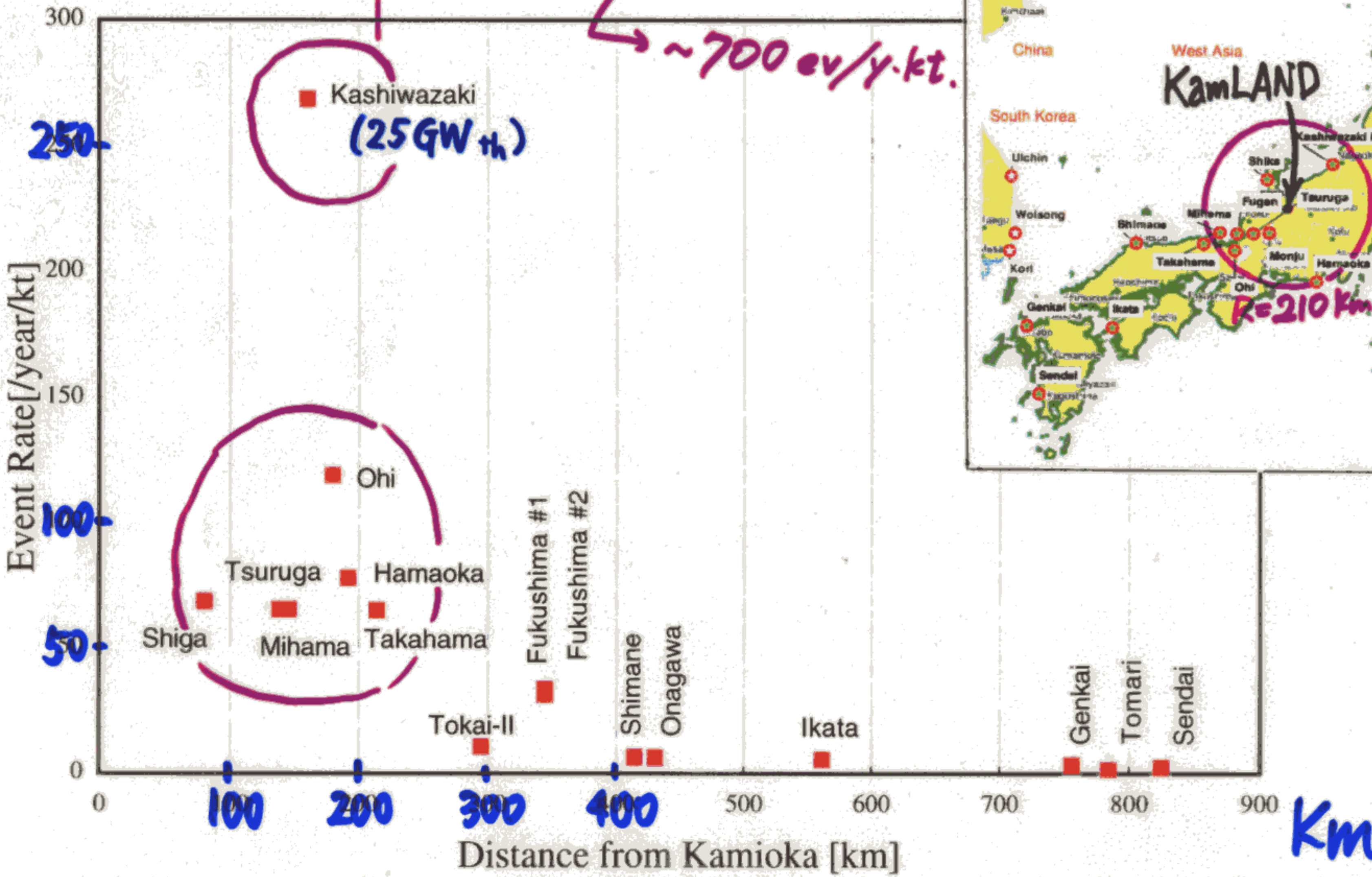
Powerful reactors & Large target volume

$\Phi_{\bar{\nu}_e} = 1.3 \times 10^6 \ cm^{-2} \cdot s^{-1}$ (>1.8 MeV)

More than 50% of Japanes reactors' power! → 70GW

80% of Φ_ν from < 210 km (175 ± 35 km)

~700 ev/y·kt.



$\bar{\nu}_e$ Detection

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

$E_\nu > 1.8$MeV

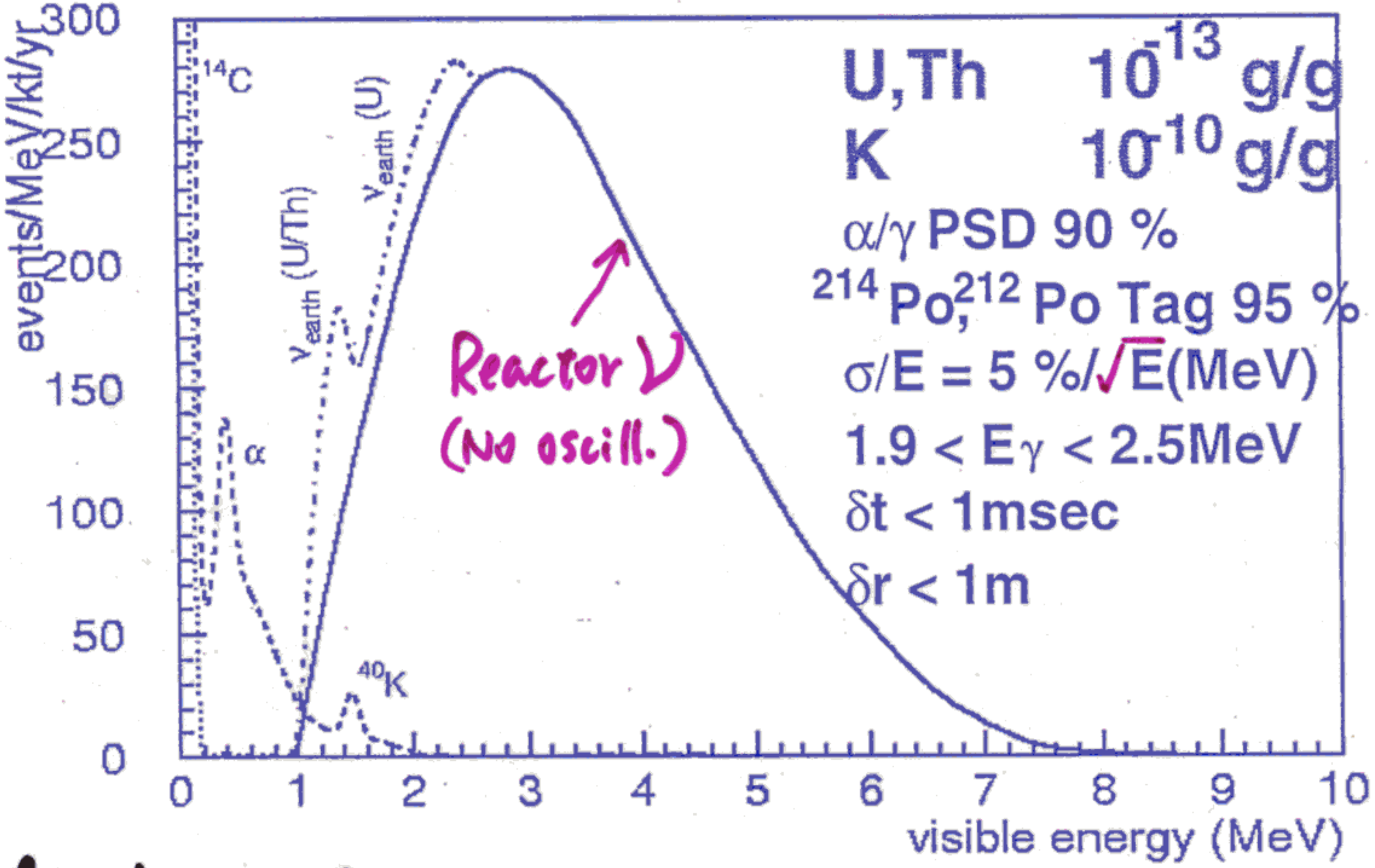
$e^+ \rightarrow e^+e^- \rightarrow 2\gamma$ (0.51MeV) "Prompt" (= E_ν -0.77MeV) ≥1MeV

$n \rightarrow$ (~180μs) $np \rightarrow d\gamma$ (2.2MeV) "Delayed"

"Prompt" + "Delayed" → Paired signal

- $\bar{\nu}_e$ Only
- Delayed coinsidence → Reject BG
- Large cross section (~100σ(νe→νe))
- E_ν is measured. "Prompt"
- Tagged by "Delayed" signal with correlations of time, position, energy.

Reactor $\bar{\nu}_e$ signal: $\bar{\nu}_e p \rightarrow e^+ n$



Fiducial volume = 600 ton

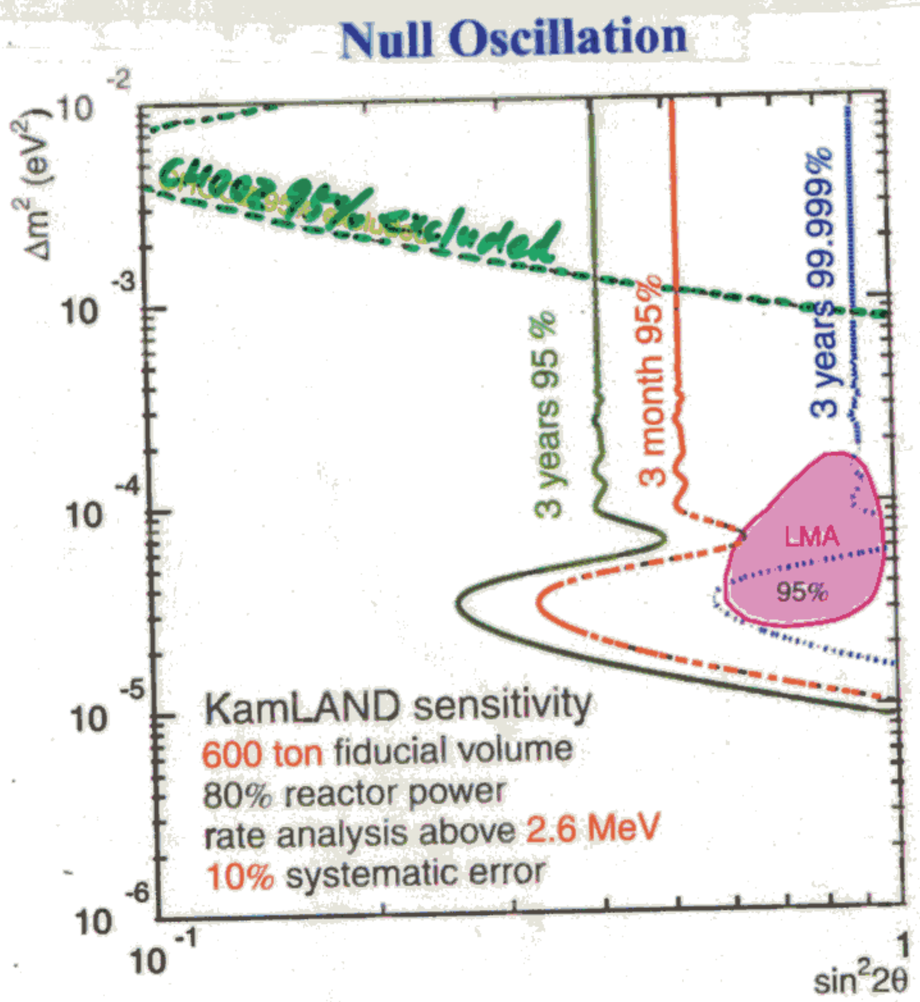
Reactor off. = 80 %

No oscill. → 550 ev/yr (Reactor), ~40 ev/yr (Geo.), Reactor 390 ev/yr (≥ 2.6 MeV, above Geo. ν)

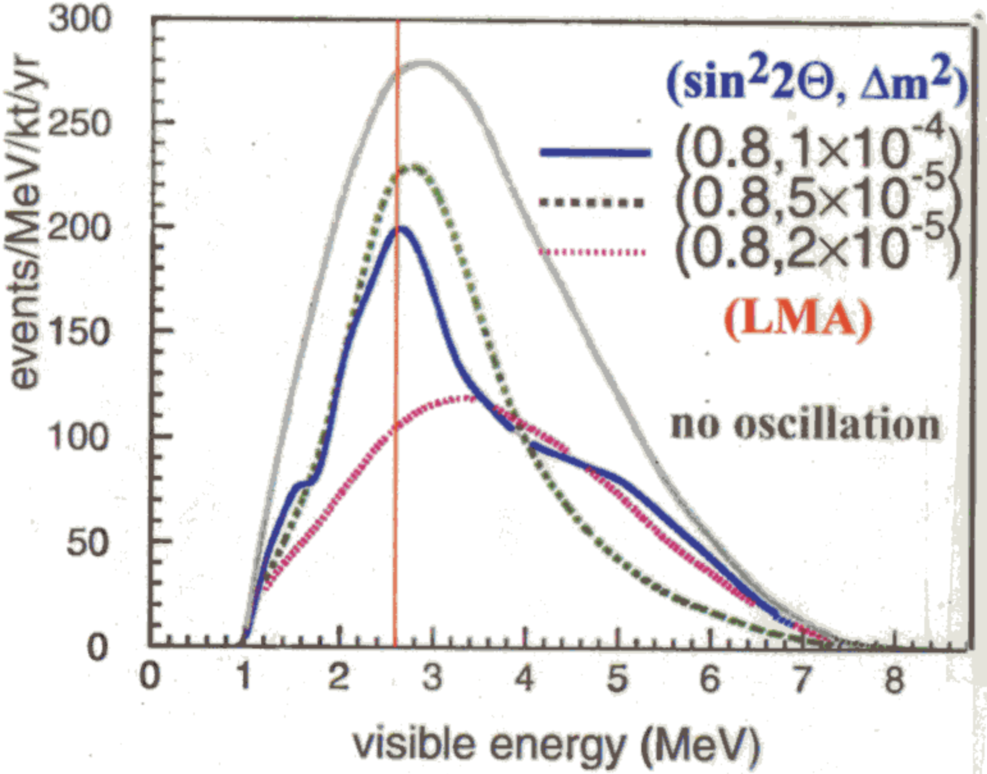
Expected Systematic Error (Goal)

Source	%
Absolute $\overline{\nu}_e$ flux	~3
Cross section	~1
Fiducial volume	~2
Absolute $E_{\overline{\nu}_e}$	~2.5
Others	~2
Total	~5 (~10 %) first phase

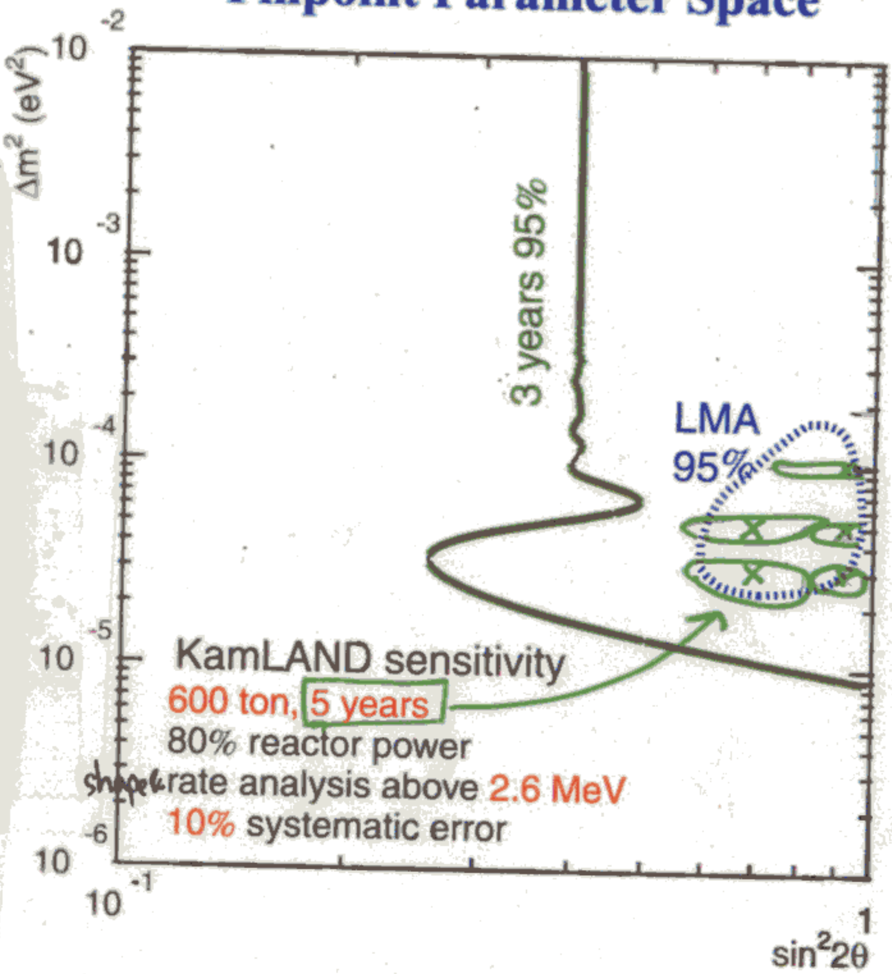
Sensitivity of $\nu_e \rightarrow \nu_x$ Neutrino Oscillation Search



Visible Energy Spectra with and without Oscillations



Pinpoint Parameter Space



Solar ν problem (SNP)

$\parallel$

Solar $^7Be\,\nu$ deficit problem

Data → No room for $^7Be\,\nu$

⇕

SSM

① Detection of $^7Be\,\nu$ → crucial to solve the SNP

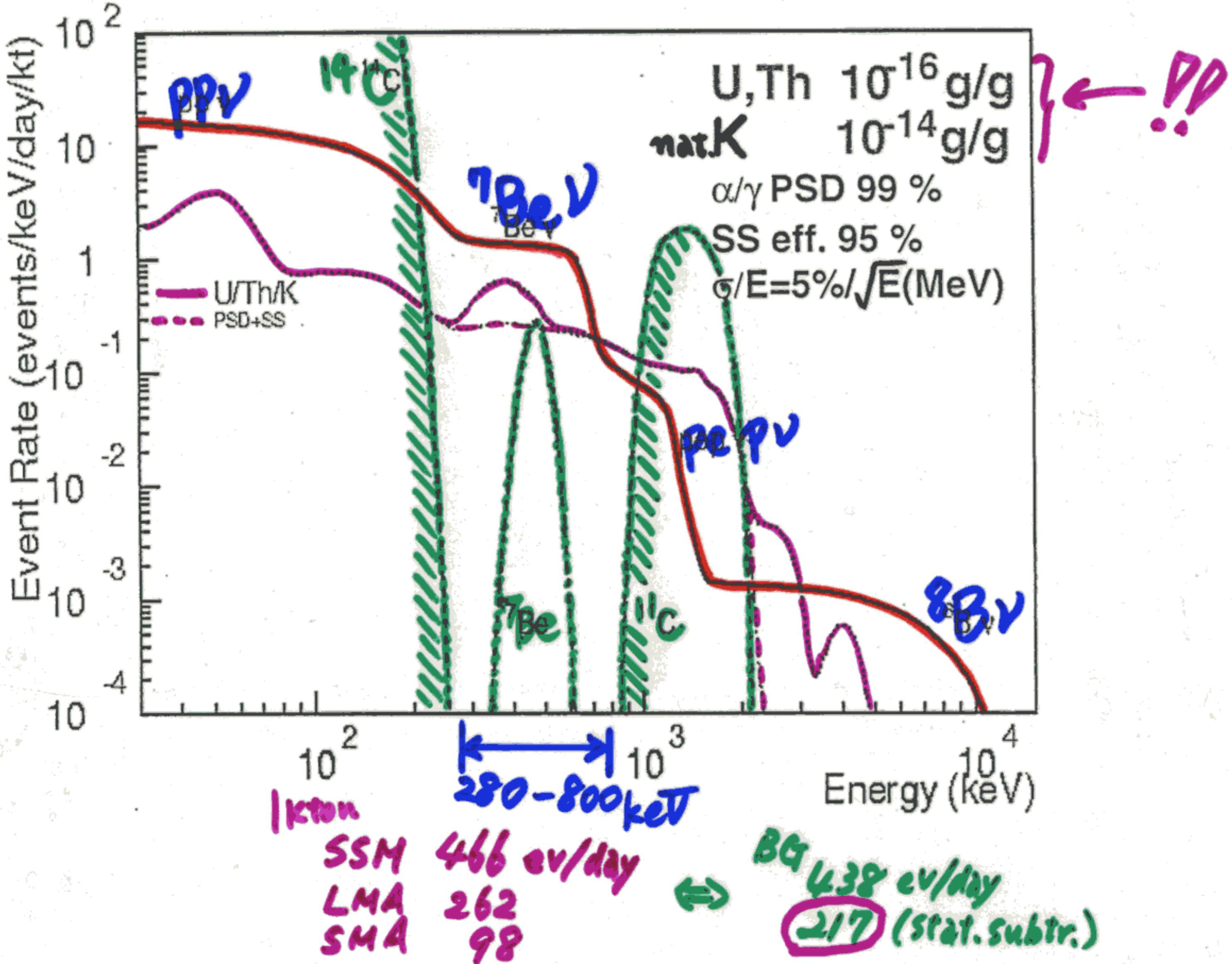
② Even if LMA is confirmed to be right or not, $^7Be\,\nu$ detection is very important!

Detection in KamLAND : $\nu_e e^- \to \nu_e e^-$, $E_\nu = 860\,keV$

- Single hit mode
- need much higher radio-purity.

Solar neutrino detection

$$\nu_e e^- \rightarrow \nu_e e^-$$

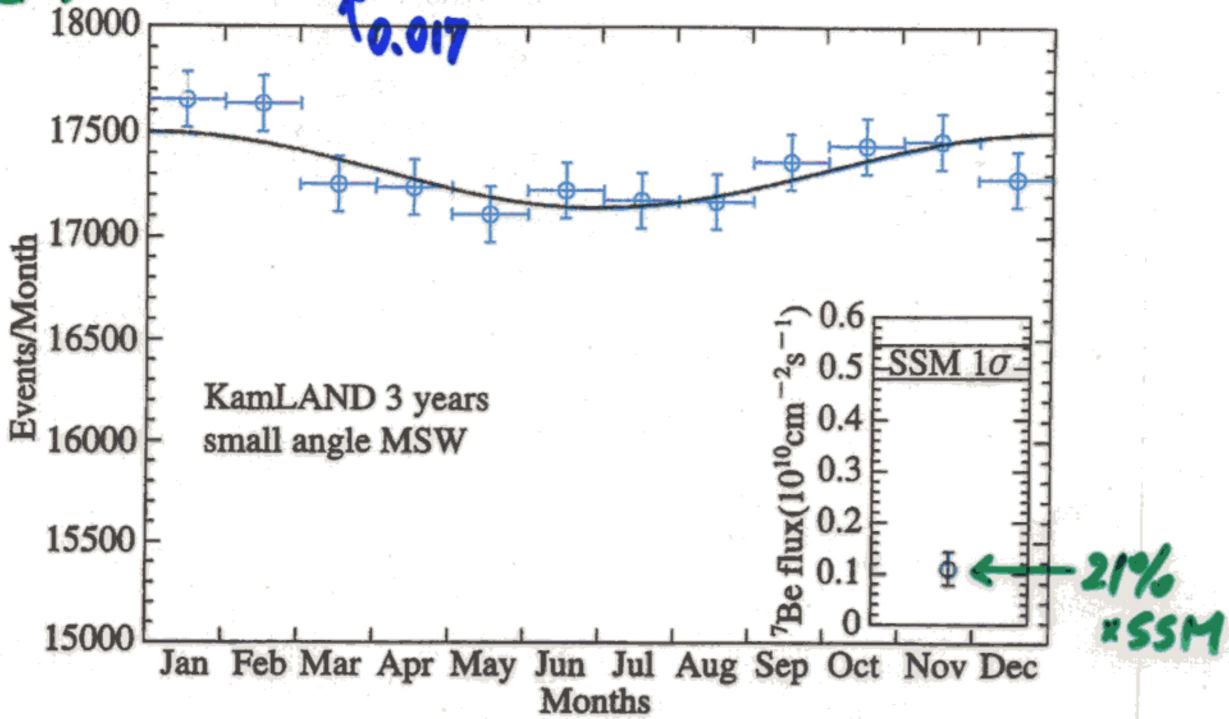


"KamLAND 3years"

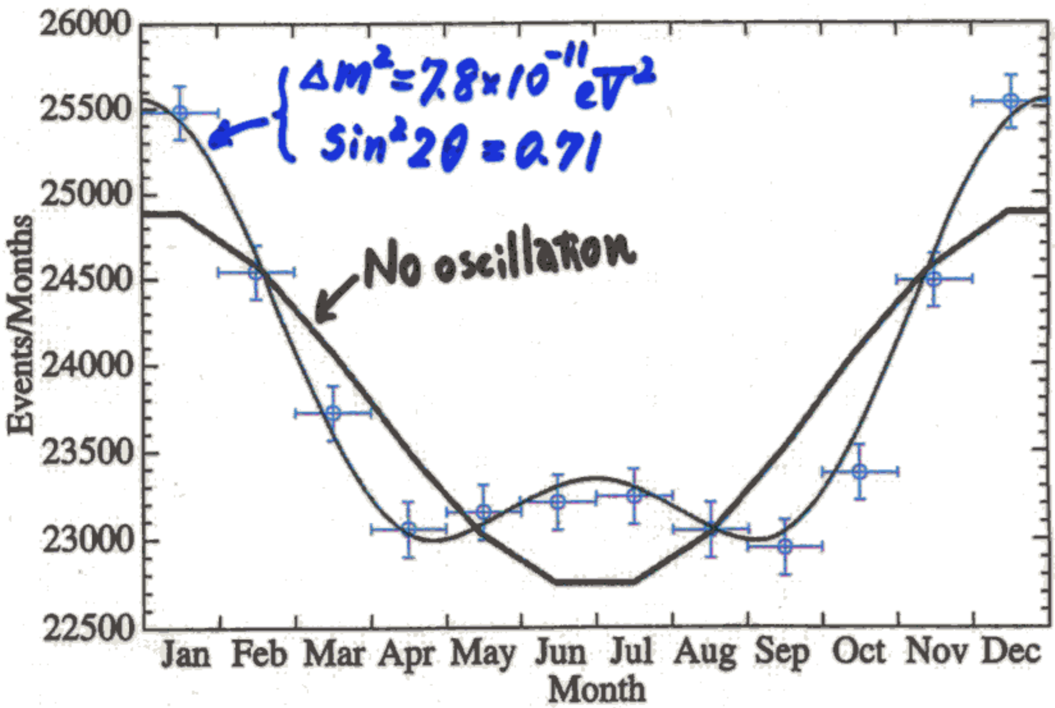
Seasonal variation of ^{7}Be solar ν

$\Phi_\nu \propto \frac{1}{L^2}$, $L = L_0(1 - \varepsilon\cos(2\pi t))$

SMA

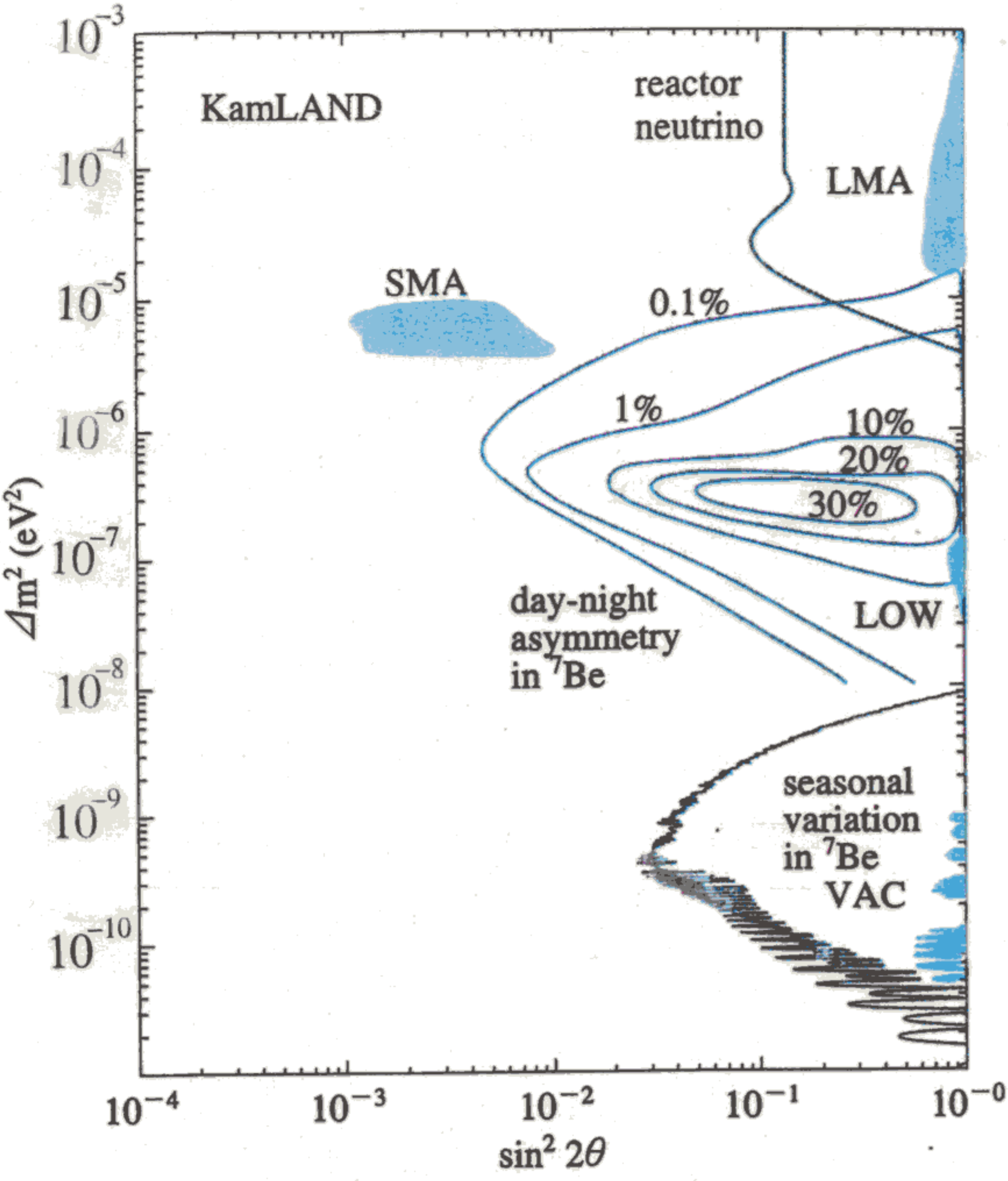


VAC



$$P(\nu_e \to \nu_e) = 1 - \sin^2 2\theta \sin^2\left[\frac{\Delta m^2}{4E} L_0 (1 - \varepsilon\cos 2\pi t)\right]$$

Sensitivity of KamLAND to the solutions of solar ν problem.



All the solutions can be checked by KamLAND! if required radiopurity is attained.

Terrestrial $\overline{\nu}_e$ Detection

To measure

Radiogenic heat
~16TW

→

Basic factor
Interior dynamics
History of the earth

~ 40% of observed total heat flow

~ 90% from U/Th decays,
expected equally from crust & mantle.

First challenge !!
Direct information of the radiogenic heat generation
Constraints models of the earth
Something New!

Terrestrial anti-neutrino detection : $\bar{\nu}_e p \to e^+ n$

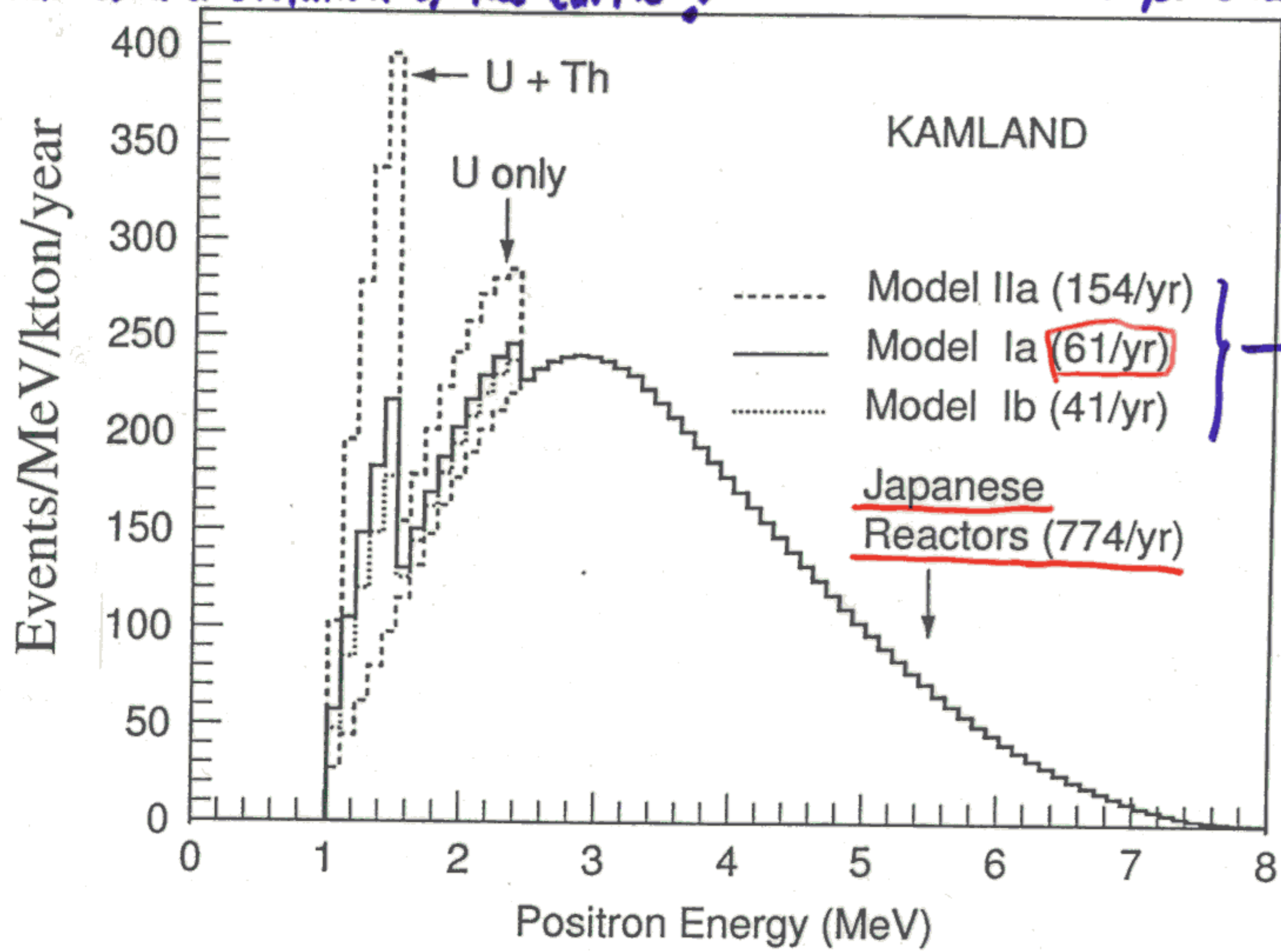
40 TW (total heat flow)

~40% : radiogenic heat (U/Th decay)

↳ $\bar{\nu}_e$: direct information on the heat production, dynamics and evolution of the earth !

Phys. Rev. Lett. 80, 635 (1998)

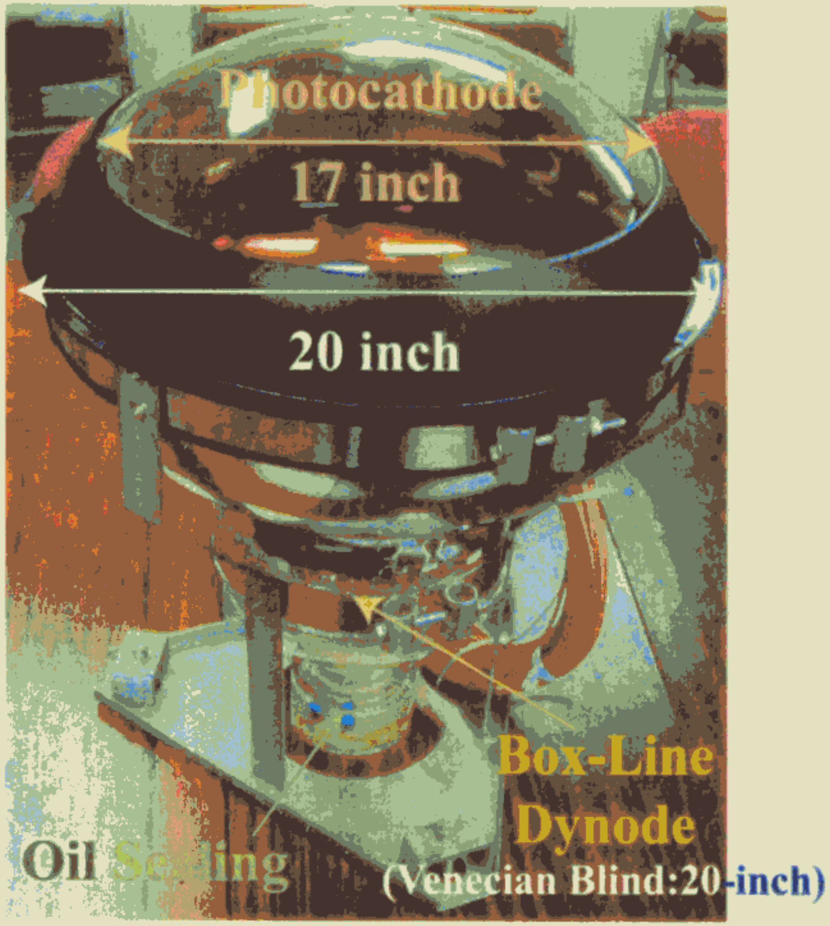
by Enomoto et al.

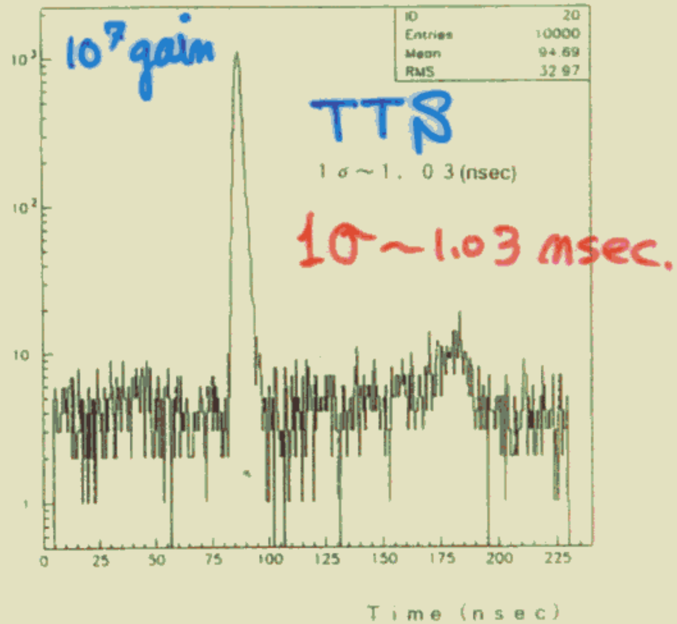


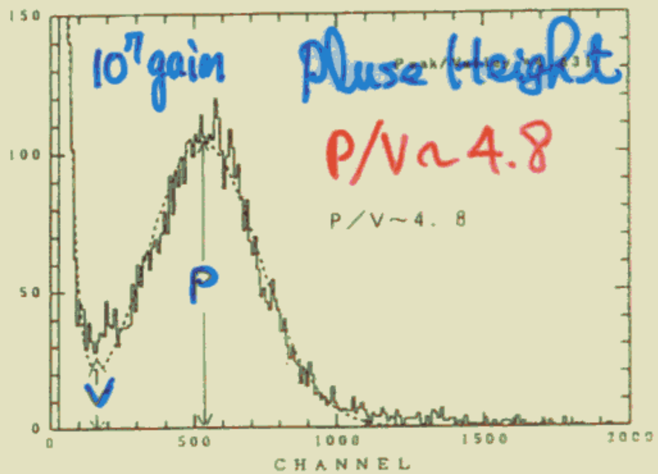
→ Models of U/Th distribution can be checked in a few years' operation.

17 inch-Photomultiplier

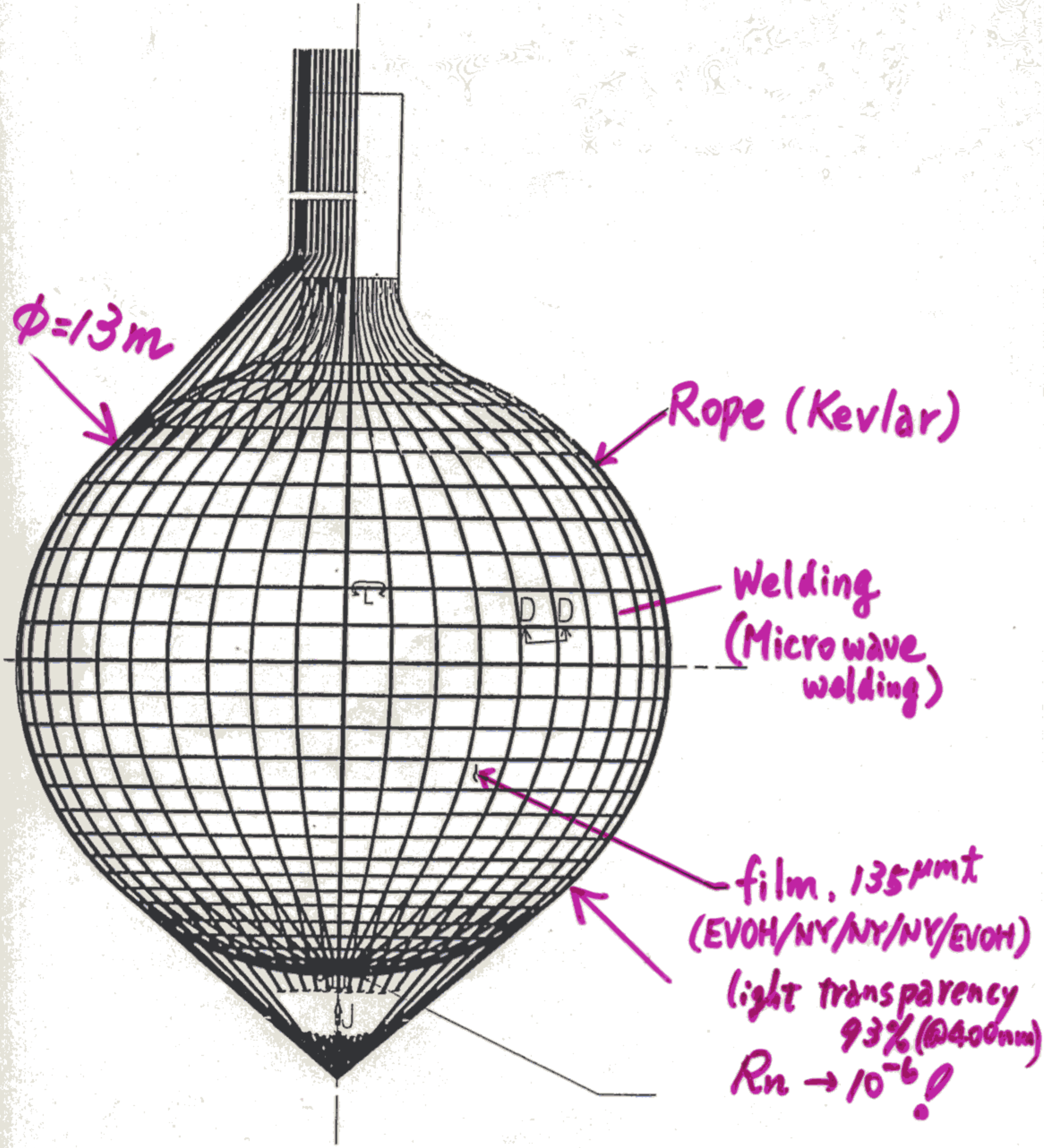
Good energy & timing response for 1 p.e. light







Balloon

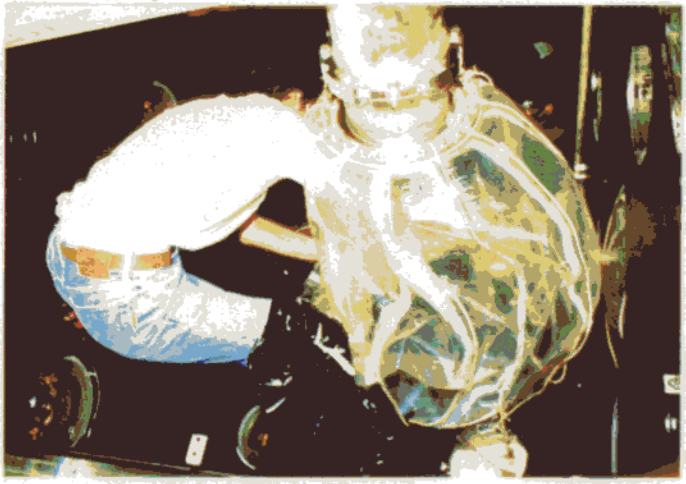


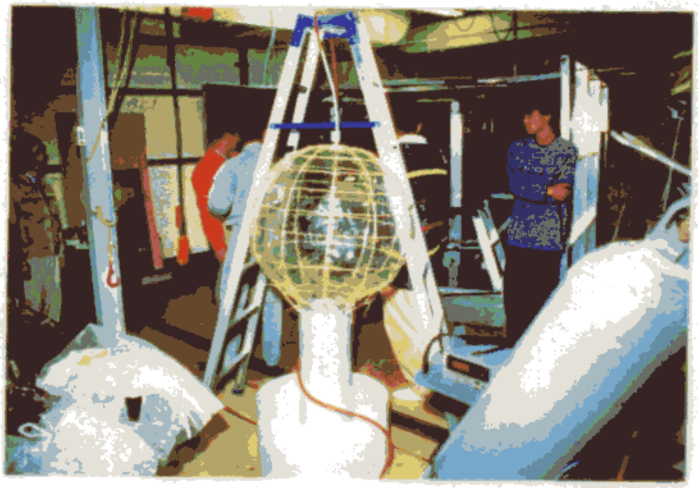
~2000.9 R&D

2000.10 ~ 2000.12 fabrication

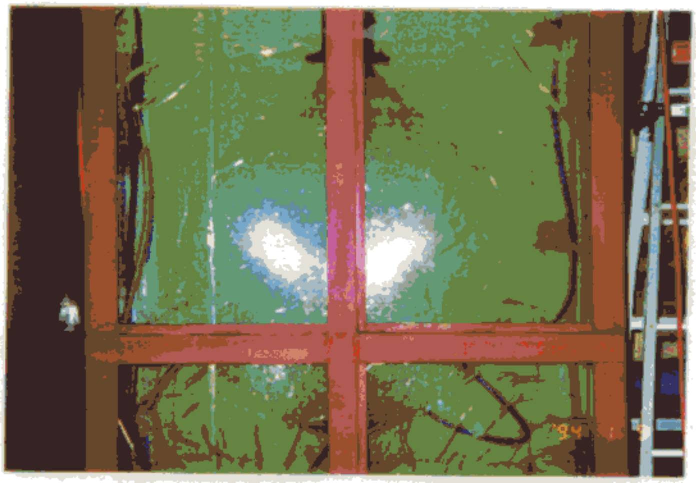
2001.1 ~ 2001.3 Installed in the tank

Many trials for balloon test! ('98-'00)

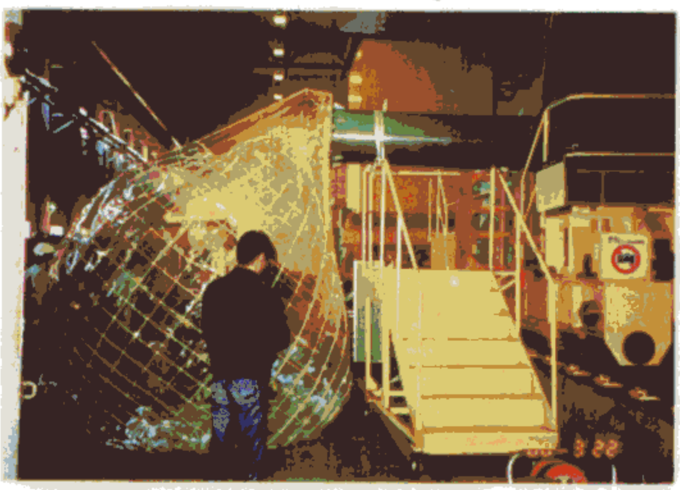


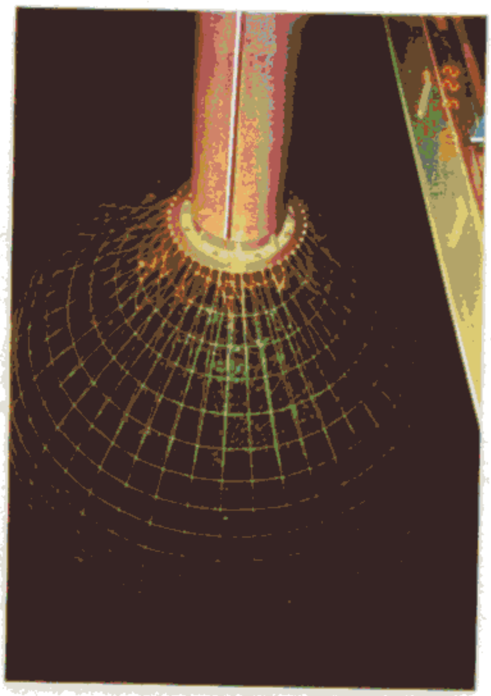


13μm t
EVOH
only



1/4 scale

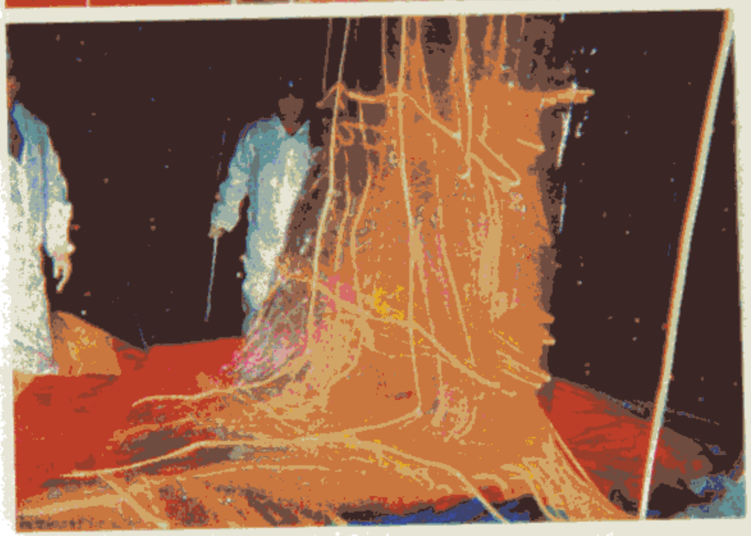




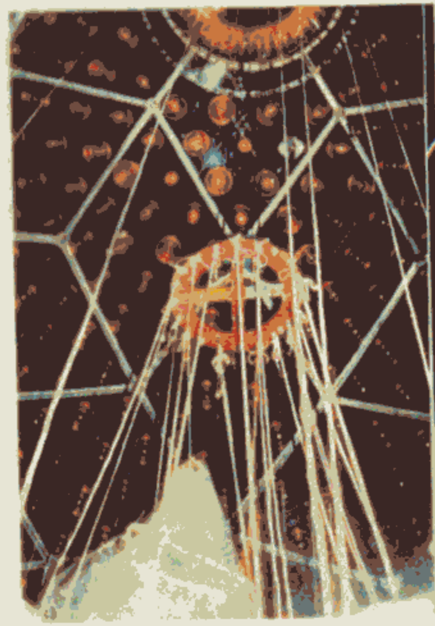
1/1 scale test balloon,
being inflated half at the factory.

Balloon Installation *(2001.1)*

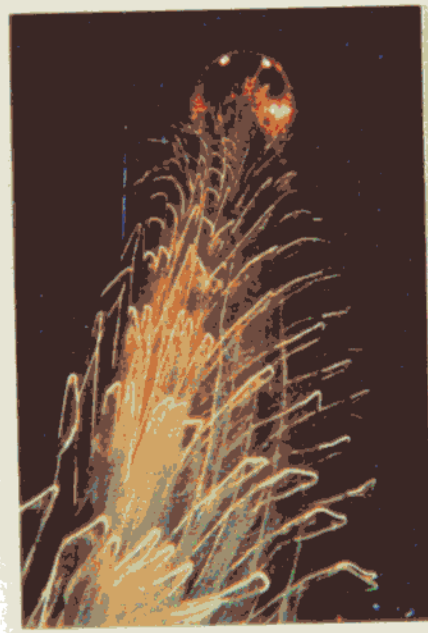
putting on the bottom of tank.



pulling up

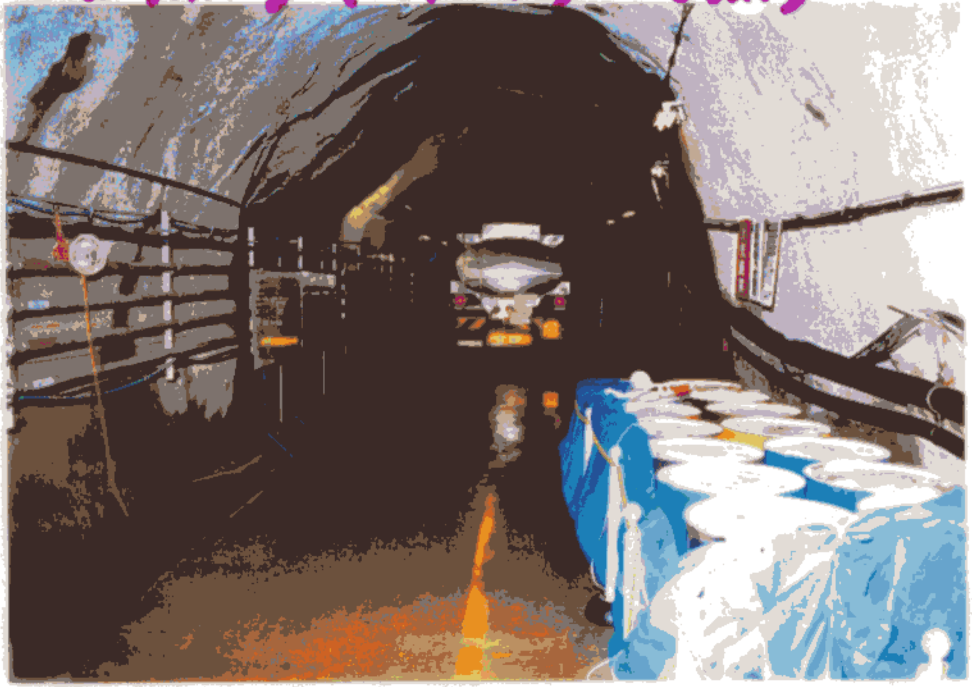


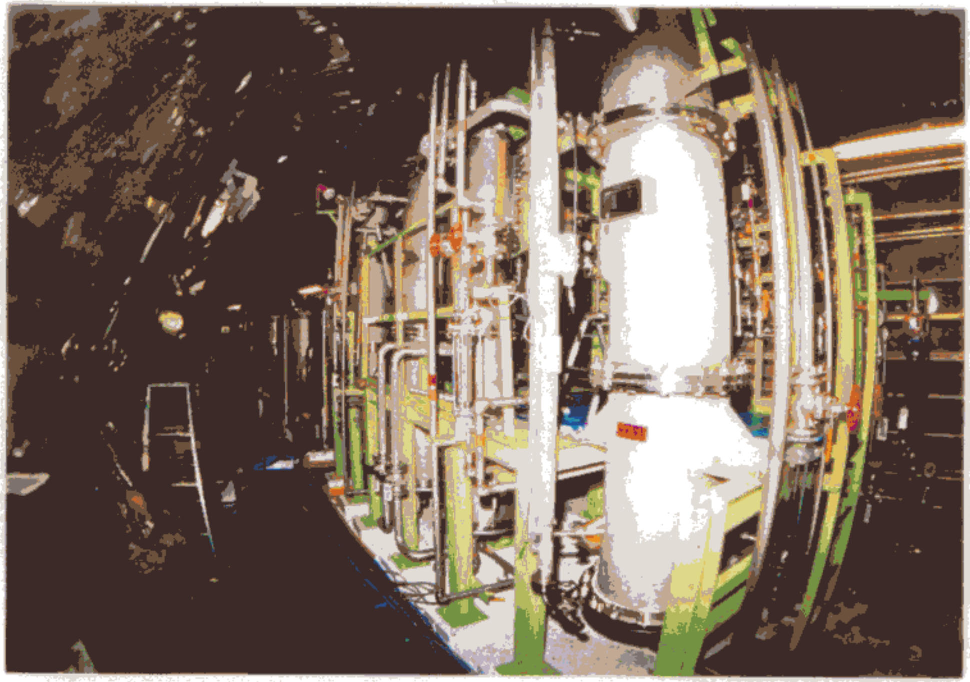
pulling up.



pulling up.

Oil filling ('01. May - Oct.)





Summary

- KamLAND : A New challenge to the m_ν problem through reactor ν & solar ν detection, and to the first observation of terrestrial ν.
- Detector construction and the oil filling were finished, and the system has been ready for reactor ν experiment.
- Data taking has been started on Jan. 22 at 0:30pm !