KamLAND double beta decay experiment using ^{136}Xe

(KamLAND-Zen)

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- summary of KamLAND
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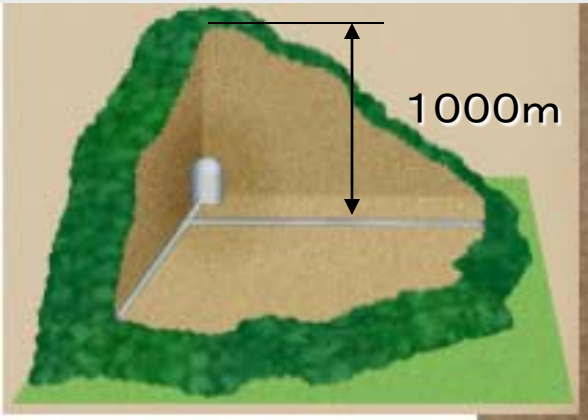
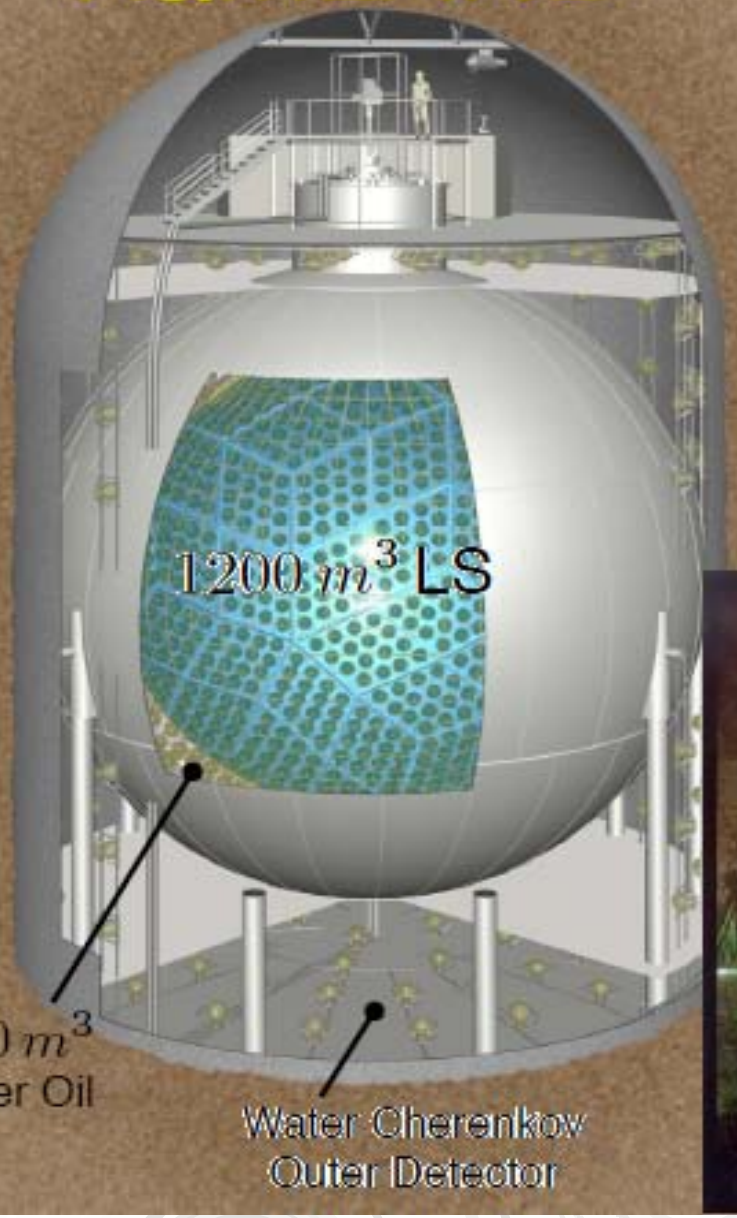
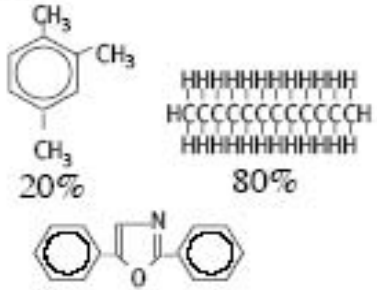


KamLAND



LS



$\rho = 0.78 g/cm^3$

$8,000 photons/MeV$

$\lambda \sim 10\,m$

34% photo-coverage
with
1325 17" and 554 20"
photo-tubes

BO

50% dodecane
50% isoparaffin

$$\frac{\rho_{LS}}{\rho_{BO}} = 1.0004$$

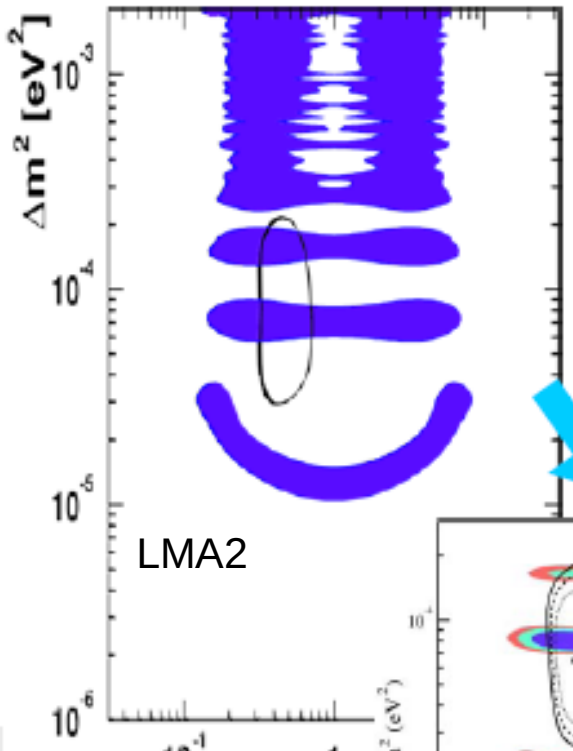
Summary of KamLAND

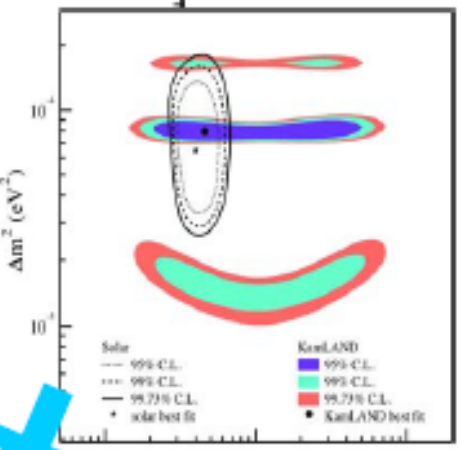
- 1998-2001: construction
- 2002: data-taking start
- We got some results
  - reactor anti-neutrino observation
    neutrino deficit at ~175km base
    spectral distortion
    precise oscillation parameters measurement

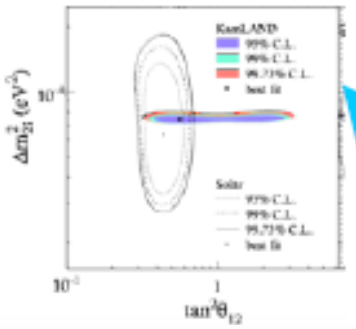
KamLAND only	$\tan^2\theta = 0.56^{+0.14}_{-0.09}$	$\Delta m^2 = 7.58^{+0.21}_{-0.20} \times 10^{-5}\ \mathrm{eV}^2$
KamLAND + SNO	$\tan^2\theta = 0.49^{+0.07}_{-0.05}$	$\Delta m^2 = 7.59^{+0.20}_{-0.21} \times 10^{-5}\ \mathrm{eV}^2$

  - Geo neutrino detection
- 2009~: KamLAND is running for ^{7}Be solar neutrino observation after the LS distillation
- 2011~: Xe phase

Reactor Anti-Neutrino

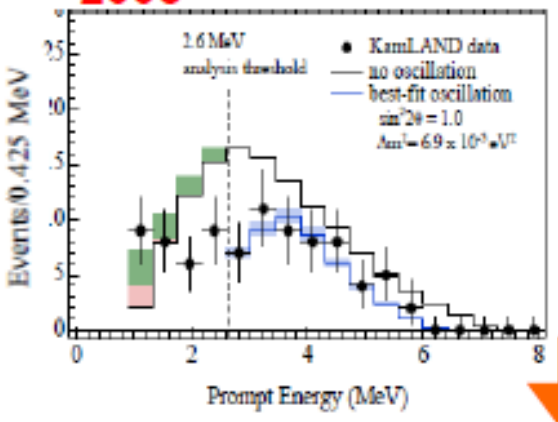


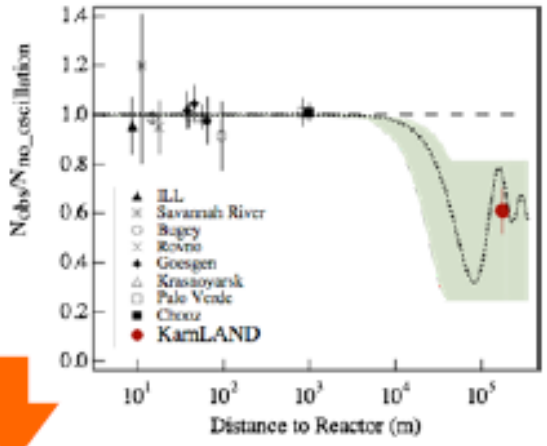




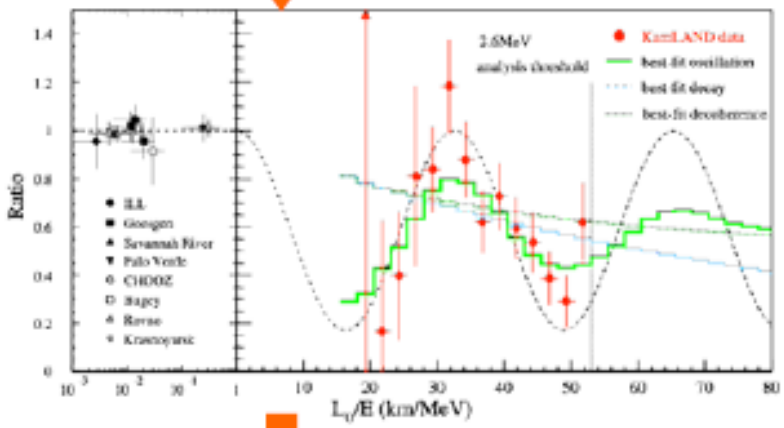
~2007

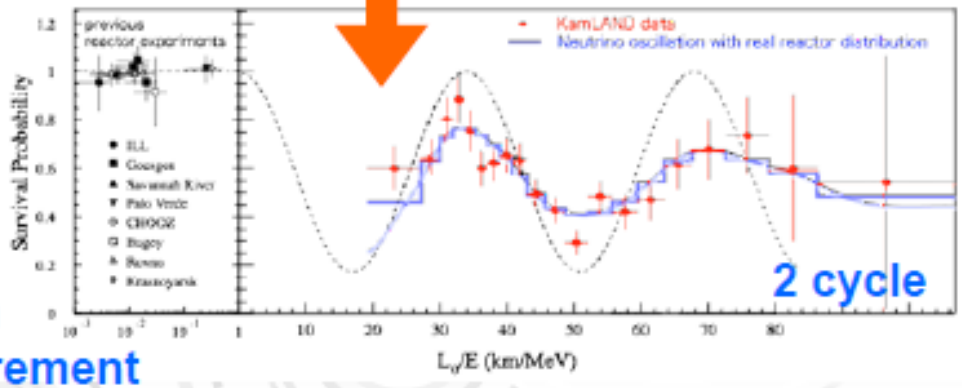
2003





~2005





Precise oscillation Parameter measurement

Geo Neutrino observation

Radio active nuclei produce heat

$^{238}U \rightarrow {}^{206}Pb + 8\,^{4}He + 6e^{-} + 6\bar{\nu}_e +$ **51.7MeV**

$^{232}Th \rightarrow {}^{208}Pb + 6\,^{4}He + 4e^{-} + 4\bar{\nu}_e +$ **42.7MeV**

$^{40}K \rightarrow {}^{40}Ca + e^{-} + \bar{\nu}_e +$ **1.31MeV**

Terrestrial heat flow 31~44TW

Contribution of radioactive nuclei **~20TW**

(U series 8TW / Th series 8TW / ^{40}K 4TW)

from Crust + Mantle

-- based on Chondrite model (BSE model)

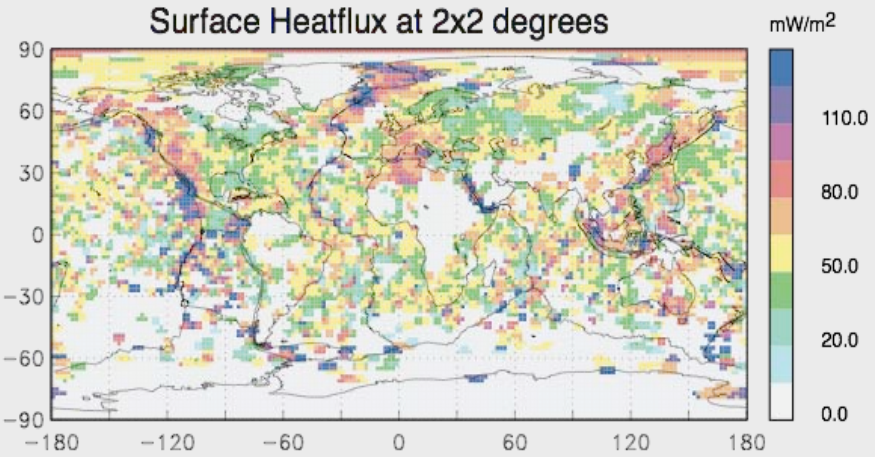
Upper crust of land

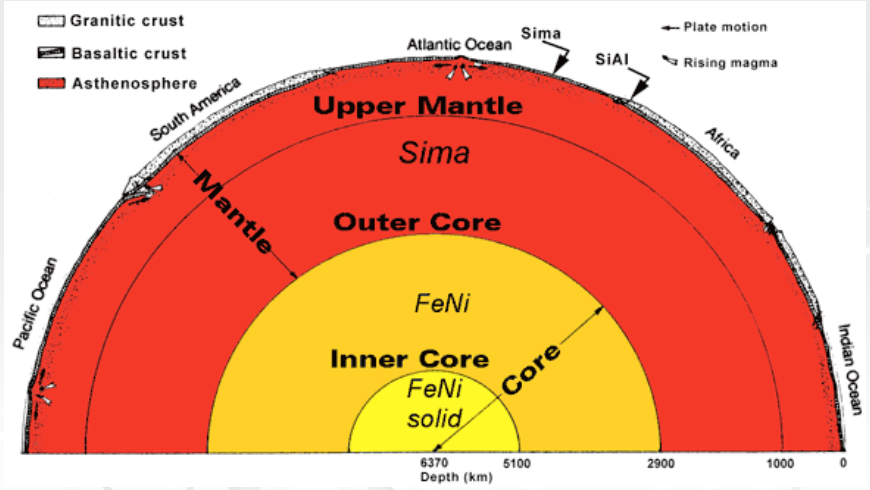
U:2. 8ppm / Th: 10.7ppm

Rudnick et al (1995)

No radiogenic heat from the core

Th/U ratio ~3.7





Geo Neutrino observation

- preliminary result (K.Inoue, Neutrino2010)

data set : March 9, 2002 ~ November 4, 2009

total exposure: 3.49×10^{32} target−proton−years

841 candidates in 0.9 - 2.6MeV

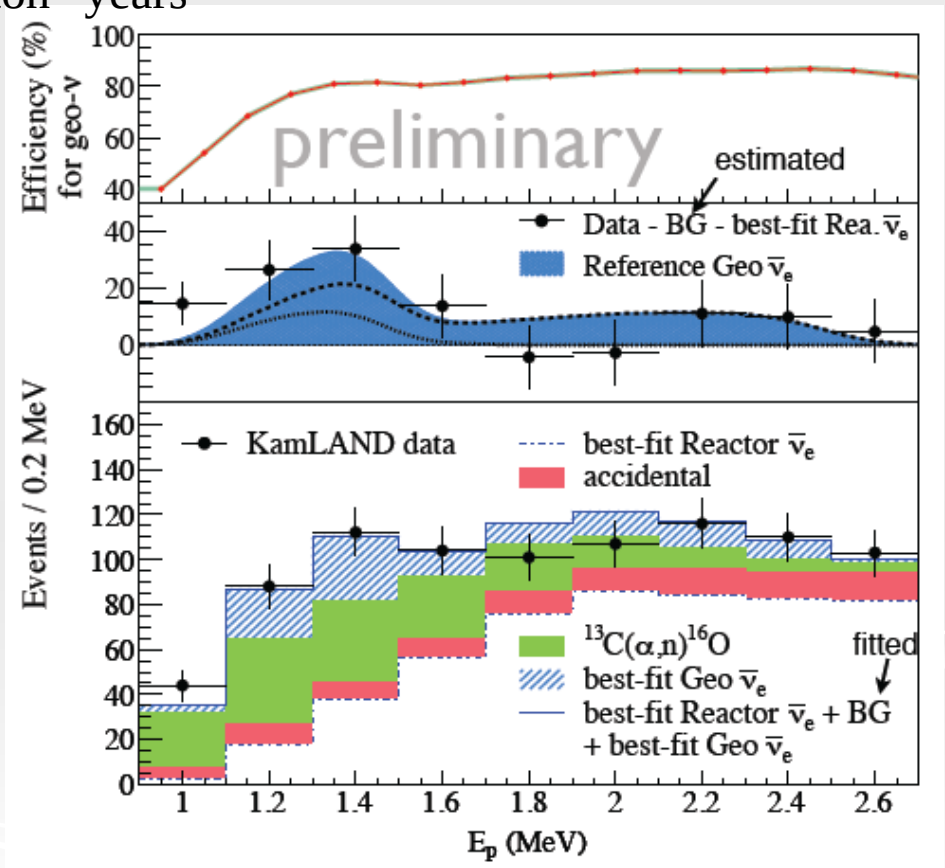
BG total 729.4 ± 32.3

reactor $\bar{\nu}_e$	484.7 ± 26.5
$^{13}C(\alpha,n)^{16}O$	165.3 ± 18.2
accidental	77.4 ± 0.1
9Li	2.0 ± 0.1
atm.ν + fast n	< 2.8

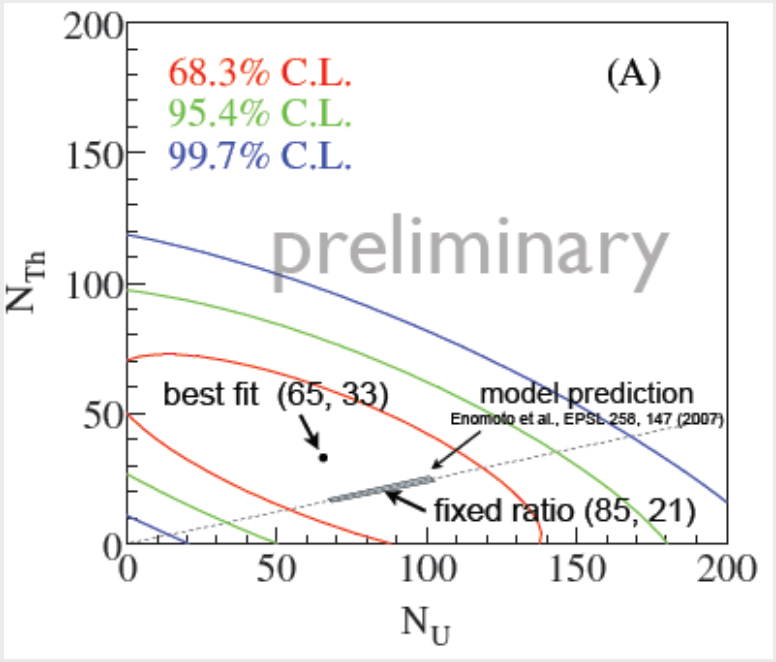
rate - only analysis $111\ ^{+45}_{-43}$ events

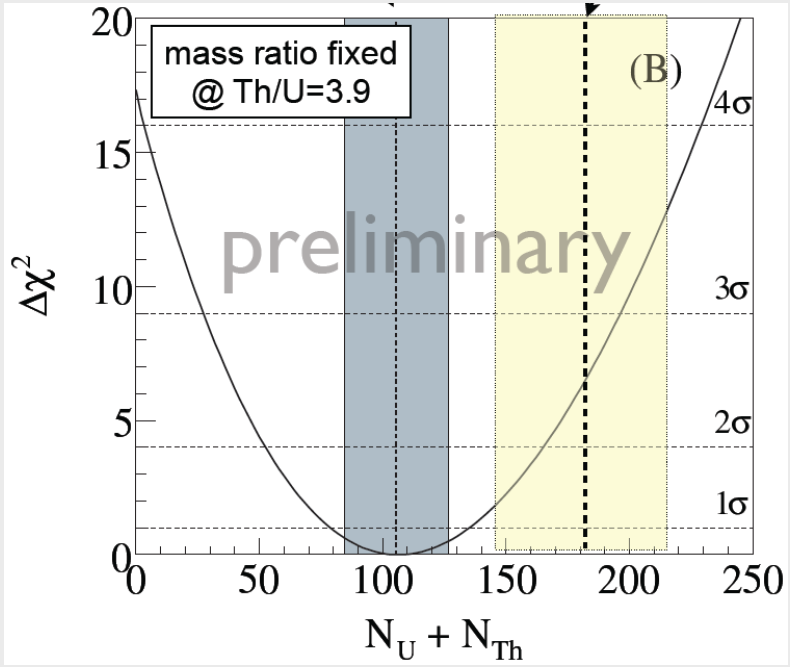
Null signal exclusion 99.55%

(rate - only hypothesis test)



Rate-Shape-time analysis





0 signal is rejected at 99.997%CL.(>4σ)
(rate-shape-time $\Delta\chi^2$)

# of geo-ν events 106^{+29}_{-28}

$4.3^{+1.2}_{-1.1} \times 10^6$ /cm^2/sec

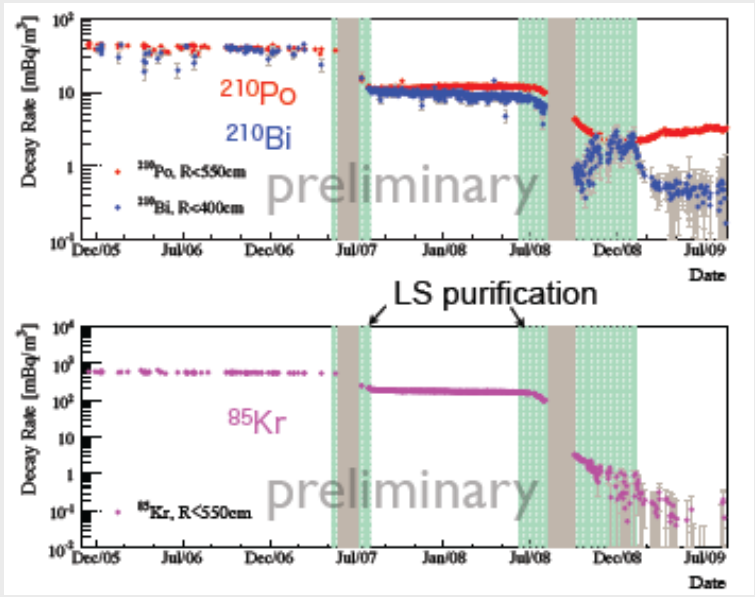
$38.3^{+10.3}_{-9.9}$ TNU

corresponds to 16TW (for U+Th)

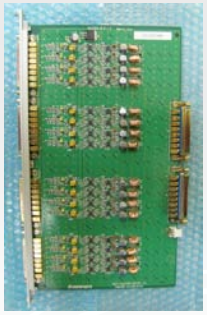
Consistent with the model prediction

^{7}Be neutrino observation

LS was purified by the distillation system
(2007 and 2008)



Installed new electronics – for ^{13}C(α,n) background reduction (on going)



Data-taking continue (to March 2011)

KamLAND Zen experiment
(KamLAND zero neutrino Double Beta decay)

RCNS Tohoku University

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IPMU Tokyo Universisty

A.Kozlov

University of Tennessee

Y.Efremenko

Colorado State university

B.E,Berger, D.Warner

TUNL

W.Tornow, D.Markoff, H.Karwowski

Advantage for ββ experiment on KamLAND

- KamLAND has

  huge volume: 1,200m^3 Liquid Scintillator

  Ultra low radioactivity

  Low threshold : (It will be E_{th}= few 100keV)

  established distillation technique

  experience of balloon development

  new electronics (from 2009)

  mach advantage for 0νββ experiment !

- Disadvantage

  Current Energy Resolution:

$$\Delta E = \frac{6.2\%}{\sqrt{\mathbf{E(MeV)}}}$$ (34% photo coverage)

This is enough on earlier stage !

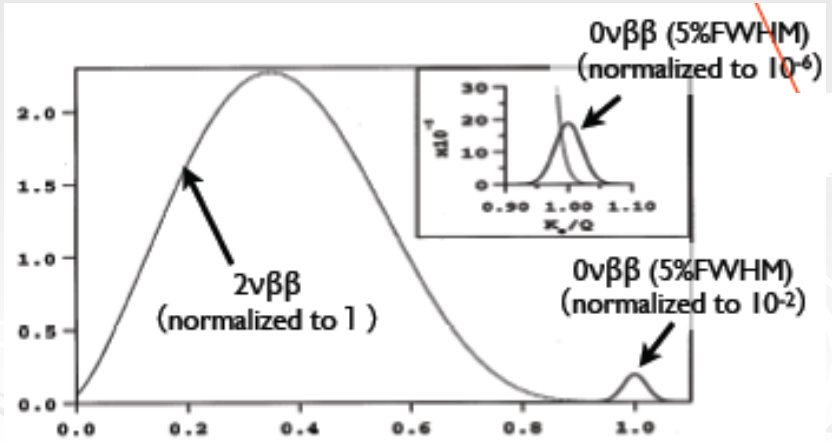
KamLAND-Zen project

Merit of using ^{136}Xe on KamLAND

Nucleas	$T^{0\nu}_{1/2}$(50 meV)	$T^{2\nu}_{1/2}$ measured (year)	Nat.Abundane (%)	Q-value (keV)
$^{136}Xe \rightarrow {}^{136}Ba$	4.55×10^{26}	$>10^{22}$	8.9	2476

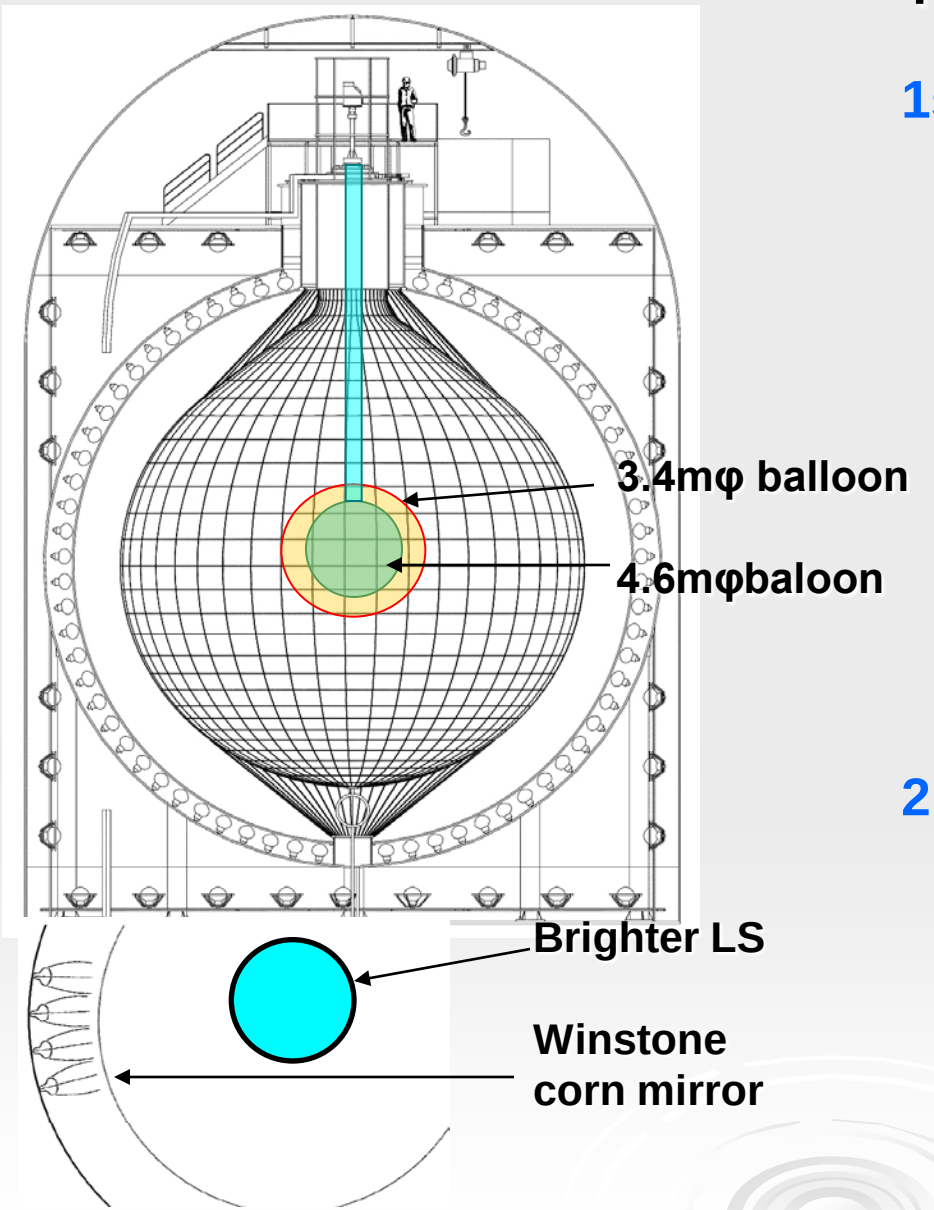
Rodin et al., Nucl. Phys. A793 (2007)213-215

- Available the Isotopic enrichment (>90%)
- purification method was established
- solubility to LS > 3%, easy extracted
- slow $2\nu\beta\beta$ ($T^{2\nu}_{1/2} > 10^{22}$ years)
  small $T^{0\nu}/T^{2\nu}$ ratio



* basic idea by R.S.Raghavan
Phys. Rev.Lett.72 (1994)

KamLAND-Zen project



1st phase enriched Xe 400kg

R=1.7m balloon

V=20.5m^3,S=36.3m^2

LS : C10H22(81.8%)+PC(18%)

+PPO+Xe(~2.5wt%)

ρLS： 0.78kg／ℓ

high sensitivity with low cost

tank opening (2013 or 2015)

2nd phase enriched Xe 1000kg

R=2.3m balloon

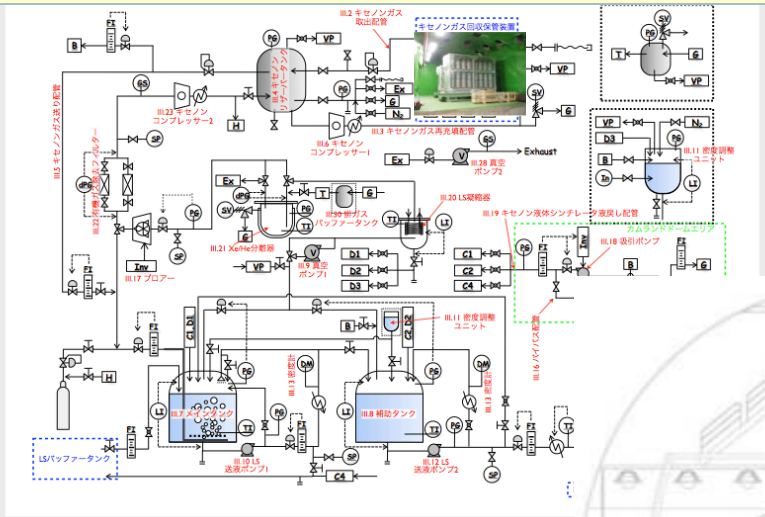
V=51.3m^3,S=66.7m^2

improvement of energy resolution

(brighter LS, higher light concentrator)

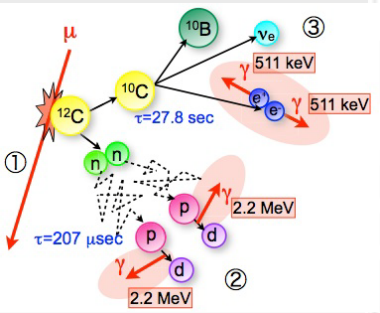
Developments of system for 400kg Xe phase

1. Xe gas loading/ extraction system



System will be ready in December 2010

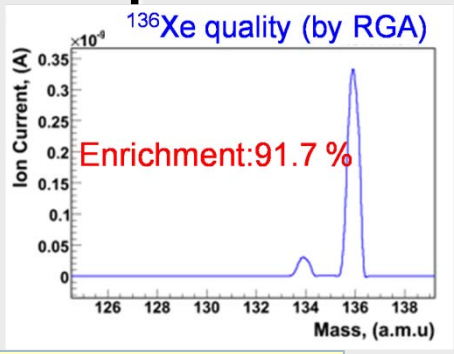
2. New electronics - MOGURA



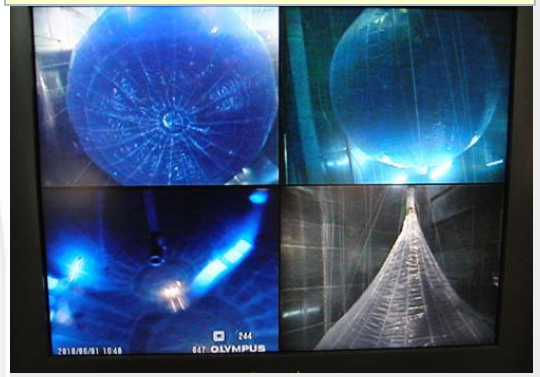
For BG reduction using tagging.
Installed in 2009.

3. Enriched Xe

- We have 190kg 90% enriched Xe gas
- Purchase 210kg more to March 2011 (400kg total)



4. Mini Balloon Φ3.4m



Handling and pressurized test by water (80μm film, June 2010)

More R&D

- ultra low contamination films U/Th/^{40}K ~ 10^{-13}g/g
- more thin film ~25μm

MIB will be delivered to March 2011

Background study using KamLAND MC (GEANT4)

Major BG

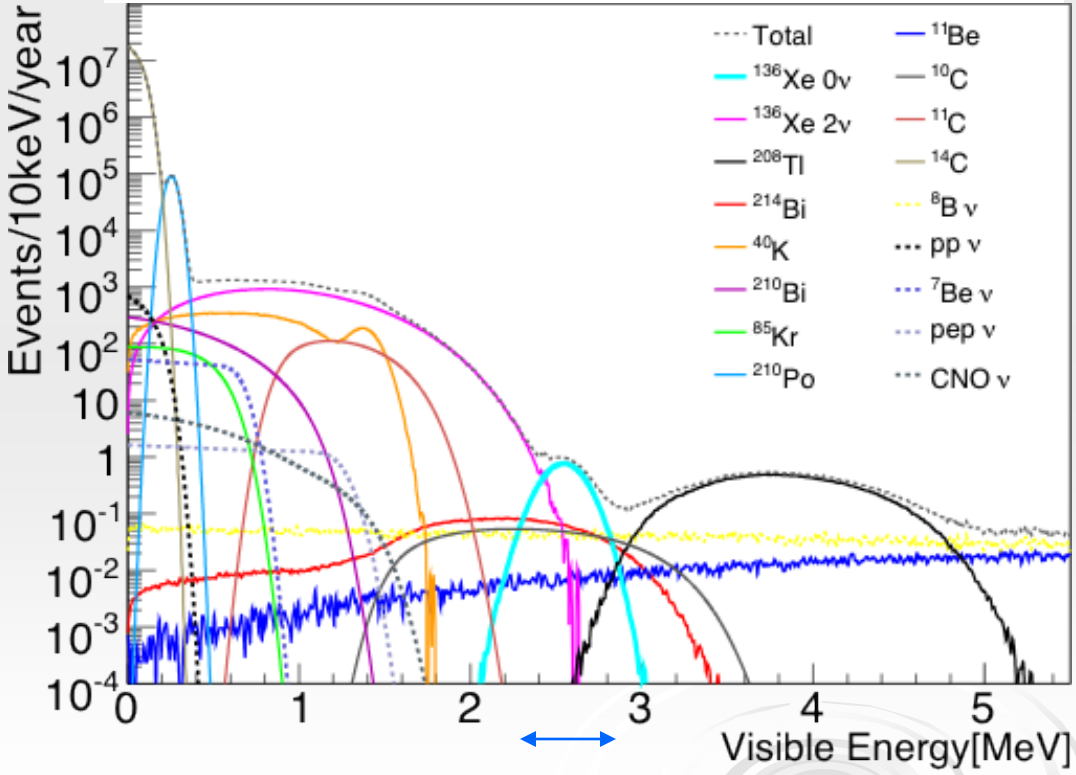
(1). ^{136}Xe 2vββ

(2). spallation isotopes : ^{10}C, ^{11}Be => 1/10 using new electronics help

(3). ^{8}B solar neutrinos <4.9 events/d/kton on KamLAND

(4). from Mini Balloon (MIB) material : ^{208}Tl, ^{214}Bi => vertex cut,

Simulated Energy Spectrum at KamLAND



Assumed
- 400kg 90% enriched Xe loaded LS
- MIB contamination (238U, 232Th, 40K) = (10-12, 10-12, 10-11)[g/g]
- neutrino effective mass <mν> = 150meV (the lower limit of the current claimed detection)
- $T_{1/2}(2\nu\beta\beta) > 10^{22}$y
- $T_{1/2}(0\nu\beta\beta) > 1.14\times10^{24}$y
- ^{10}C 90% tag, ^{214}Bi 66% tag

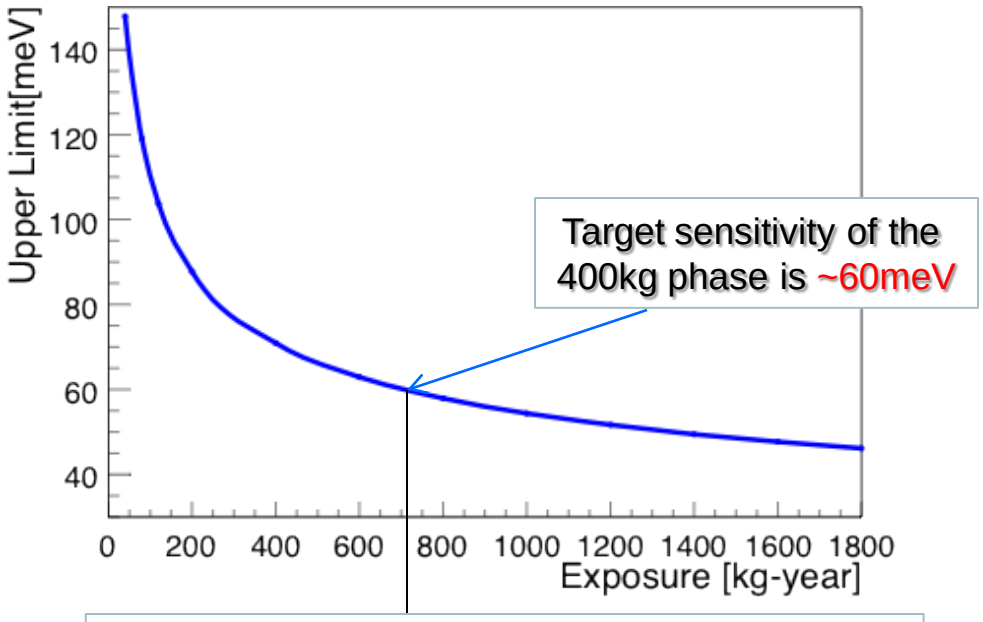
Summary of BG and signal in signal region

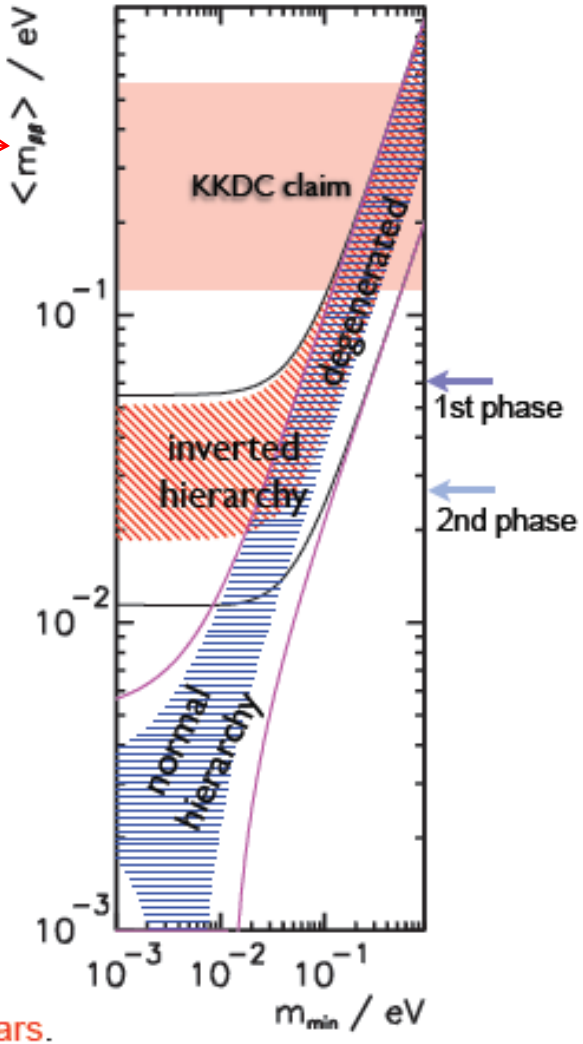
^{136}Xe 2ν	^{208}Tl	^{214}Bi	^{10}C	^{11}Be	^{8}B	Total	^{136}Xe 0ν
2.08 ±0.15	1.86×10^{-2} $\pm0.13\times10^{-2}$	2.40 ±0.01	3.09 ±0.01	0.26 ±0.01	1.52 ±0.03	9.35 ±0.23	18.08 ±0.02

[events/year]

1st phase → KKDC claim, degenerated hierarchy

$$\text{observable} = \left[T^{0\nu}_{1/2}\right] = G^{0\nu}\left|M^{0\nu}\right|^2 \left|m_{\beta\beta}\right|^2$$





2nd phase → inverted hierarchy

Target sensitivity of the 2nd phase is ~25 meV with 5 years.

summary

- KamLAND is running for reactor, Geo, 7Be solar (to 2011)
- KamLAND have ability to do 0νββ experiment
- KamLAND-Zen project will start useing 400kg 90% enriched Xe from May 2011
- Target sensitivity on 400kg Phase ~60meV @2years
- Planning Xe1000 phase (from 2013 or 2015: depend on funding)

Thank you!