Present Status of KamLAND-Zen

Yoshihito Gando
for the KamLAND-Zen Collaboration
Research Center for Neutrino Science,
Tohoku University
KamLAND–Zen collaboration

Research Center for Neutrino Science, Tohoku University

IPMU : A. Kozlov
KEK : A.Suzuki

Osaka University : S.Yoshida

University of Tennessee : Y.Efremenko

Colorado State University : B.E.Berger

TUNL : W.Tornow, D.Markoff, H.Karwowski

University of Washington : S.Enomoto
Contents

- KamLAND with 0νββ decay search
- Production of mini-balloon
- Installation of mini-balloon and Xe loaded LS filling
- Future upgrade
- Summary
Contents

- KamLAND with $0\nu\beta\beta$ decay search
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with no analysis results

Sorry for Giorgio!
KamLAND with 0νββ decay search
KamLAND: calorimeter type detector

1,000 tons pure liquid scintillator (LS)

Buffer oil: for environmental radiation
PMT: 17inch:1325 + 20inch:554

13m
18m

1000m

Shield of cosmic ray background
~10^{-5} than ground

Water cherencov anti counter
225 20inch PMT with water

Resolution: ~12cm / $\sqrt{E(\text{MeV})}$
~6.4% / $\sqrt{E(\text{MeV})}$
KamLAND LS

Solubility of ions:
- water \(\gg\) LS
- wash scintillator with water

\[ ^{238}\text{U} : 3.5 \times 10^{-18}\text{g/g} \]
\[ ^{232}\text{Th} : 5.2 \times 10^{-17}\text{g/g} \]

2\(^{\text{nd}}\) purification April. 2007 ~ Feb. 2009
- Distillation for Bi (Pb), Tl, K, U, Th
- \(\text{N}_2\) purge for Rn, Kr, Ar

\[ ^{238}\text{U} : 0.2\sim2.2 \times 10^{-18}\text{g/g} \]
\[ ^{232}\text{Th} : 1.9\sim4.8 \times 10^{-17}\text{g/g} \]

- Very low radioactive impurities
- Large volume

Suitable detector for 0\(\nu\beta\beta\) search
$^{136}\text{Xe}$ with KamLAND

- **Merit of using $\text{Xe}$**
  - isotopic enrichment, purification established
  - soluble to LS more than 3 wt%, easily extracted
  - slow $2\nu\beta\beta$ requires modest energy resolution

- **Merit of using mini-balloon**
  - suppress volume depending B.G spallation products, solar $^8\text{B}$ neutrinos

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Percentage</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decane</td>
<td>82%</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>PPO</td>
<td>2.7g/l</td>
<td></td>
</tr>
<tr>
<td>Xenon</td>
<td>2.5wt%</td>
<td>(91% Enriched $^{136}\text{Xe}$)</td>
</tr>
</tbody>
</table>
$^{136}\text{Xe}$ with KamLAND

- Same light yield between Xe-LS and KamLAND-LS

If lighter Xe-LS $\rightarrow ^{208}\text{Tl}$ will be in the signal region

If darker Xe-LS $\rightarrow 2\nu\beta\beta$ will be in the signal region because of bad resolution

$<m>=150\text{meV}$

- 2 years : $\sim 80\text{meV}$
- 5 years : $\sim 60\text{meV}$
Xe loaded LS properties

- Xe gas is soluble to LS more than 3 wt%
- Light yield is reduced depending on Xe amount in LS
  - PPO 1.36g/L → PPO 2.7g/L
- Density increasing by xenon dissolution to LS
  (to avoid tension to mini-balloon)

KamLAND-LS  PC(20%), Dodecane(80%), PPO

Xe-LS  PC(18%), Decane(82%), PPO, Xenon
Film conditions

**Nylon film**: strong, good LS compatibility
- Thick: strong, low Xe transparency, high B.G.
- Thin: weak, high Xe transparency, low B.G, α tagging

- Welding connection between films could be done
- Contamination level
  - \( ^{238}\text{U} \): \( 2 \times 10^{-12} \text{g/g} \)
  - \( ^{232}\text{Th} \): \( 3 \times 10^{-12} \text{g/g} \)
  - \( ^{40}\text{K} \): \( 2 \times 10^{-12} \text{g/g} \)
- Fracture intensity: 4.9kg/cm
- Light transparency: 99.4% ± 0.3% @400nm
- Xe transparency: < 1.3kg
  (\( r = 1.58 \text{m balloon, 5year case} \))

- \( \epsilon(^{214}\text{Po, } \alpha \text{ pass}) \): ~80%
- \( \epsilon(^{214}\text{Bi, } E_{\beta\gamma}>0.3\text{MeV}) \): ~65%
- Total tagging \( \epsilon \): ~52%
mini-balloon design

- Corrugated nylon tube
- Strings: Vectran
- Film belt by clean nylon
- Strait part
- Cone part
- Sphere part (24 gores)
- Corrugated nylon tube
- No low B.G. strings
  - Far from mini-balloon: Vectran string
  - Near mini-balloon: Film belt made by clean nylon
- Guide ring for string
Production of mini-balloon
mini-balloon production in class 1 super clean room

May ~ Aug., 2011

Film:
- ultrasonic cleaning by ultra-pure water

Film check by eye

Film cut

-balloon made by welding

24 gores for sphere part
Leak check & repair work

He leak check
→ Repair by glue
→ He leak check

- Good LS compatibility
- Xe tightness of the repair samples were confirmed

$^{238}$U: $<5 \times 10^{-12}$g/g
$^{232}$Th: $<5 \times 10^{-12}$g/g
$^{40}$K: $2.4 \times 10^{-12}$g/g
Installation of mini-balloon and Xe loaded LS filling
Preparation at Kamioka site

Clean room class $<10\text{~to~}100$

Corrugated tube connection

Monitoring system deployment

Strings and balloon cover setting
Monitoring system

- go in the KamLAND
- watch from outside
  → need monitoring system

2 monitoring systems were installed
Xe loading system

Xe reservoir tank
Main tank: Xe loading with bubbling (or Xe recovered by vacuum, He/N2)
Sub tank: final density adjustment to send Xe-LS to mini-balloon

Density control: 0.005~0.01%
Recovery efficiency: 99.99%~99.999% (depending on carrier gas volume)
Installation methods

- Have to keep KamLAND LS for the safety of KamLAND balloon
- Access flange is ~50cm
- Deploy the folded-up mini-balloons in cover

(1) Sink mini-balloons with filling heavier dummy-LS (not Xe loaded LS)
- Remove the balloon cover

(2) Inflate mini-balloons with dummy-LS
- DAQ for leak check

(3) Replace dummy-LS with Xenon loaded LS

KamLAND-LS
mini-balloon installation Aug., 2011

- Mini-balloon and corrugated tube deployment
- Balloon went through the black sheet
- Piping line and load cell setting
Dummy-LS filling and expansion

Density of dummy-LS was +0.015% than KamLAND-LS to avoid mini-balloon floating

Filling stop was determined by
- check of tension at cone part (by camera)
- check of filling volume calculation by Xe loading system

DAQ for leak check of mini-balloon was done

Connection part between corrugated tube and film

Connection part between straight part and cone part
Xe-LS filling  Aug.~Sep., 2011

- Dummy-LS was replaced with Xe-loaded LS (0.02% density difference made layer of LS)
- LS replacement was monitored by DAQ using $^{222}$Rn events as a tracer

Vertex of $^{222}$Rn events

From top:
Draining dummy-LS

From bottom:
Filling Xe-LS

dummy LS
Xe-LS

+0.015% density
+0.035% density
After Xe-LS filling

- 330 kg Xenon was installed in mini-balloon
- DAQ for KamLAND-Zen started 24 Sep, 2011
Future upgrade
- KamLAND-Zen pressurized xenon
- KamLAND2-Zen
KamLAND-Zen pressurized xenon

180kPa with 800kg $^{136}$Xe could be kept in current or almost same size of mini-balloon

30~40 meV/5years

Option
- More cleaner film
- Scintillation film for B.G. rejection in film (U,Th,K)
KamLAND2-Zen

Future upgrades 2014~

1000kg $^{136}$Xe Pressurized $\sim 6$wt%

Winston cone
- photo-coverage $\times 2$
- photon collection $\times 1.8$

LS renewal
- KamLAND LS 8,000 $\times 1.4$
- (standard LS 12,000)

Total light yield $\times 2.5$
- Low 2νββ G.B.
- $\sim 20$meV/5years

Chimney enlargement
- Capability to accommodate CaF2, CdWO4, NaI, Pbq 144Ce, and others
Details for KamLAND-Zen

Poster session

Hardware related issues
- Liquid scintillator by R.Kato
- Rehearsal of mini-balloon installation by A.Gando
- Mini-balloon construction by T.Nakada
- Mini-balloon deployment by H.Yoshida

Trigger and analysis
- Muon veto by A.Oki
- C11 tagging by Y.Ono
- B.G. study with simulation by S.Matsuda

Future
- R&D of neutrino directional detection in LS by H.Hanakago
- KamLAND2-Zen by A.Obata
Summary

- mini-balcon installation to KamLAND and Xe loaded liquid scintillator filling to mini-balcon were finished.
- KamLAND-Zen started in Sep. 2011
- Future upgrade KamLAND-Zen pressurized xenon, KamLAND2-Zen will start few years later
supplements
KamLAND-Zen
(KamLAND with Zero Neutrino double beta decay search)
Xe loaded LS properties

PC in LS <30% & temperature <20°C -> Xe solubility >3.0 wt.%
Cleaning work

- Ultrasonic cleaning with ethanol, ultra-pure-water
- Wiping by ethanol, ultra-pure-water
- Drying by N2
- Cleaning for materials and devices
  - Ultrasonic cleaning with ethanol, and ultra-pure-water
  - Brushing by toothbrush with detergent
  - Ethanol, Ultra-pure-water wiping.
  - PC, Ultra-pure-water circulation, N2 purge
Shipping

Balloon is covered by protection film

Air-tight bag filled with N₂ gas