Current status of the distillation system

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\( \nu_e \text{ from the Sun} \)
\( E < 1 \text{ MeV} \)

\( \nu_e \text{ from the Earth} \)
\( E \sim 1 \text{ MeV} \)

\( \nu_e \text{ from Reactors} \)
\( E \sim 5 \text{ MeV} \)
Importance of low energy solar neutrinos

Low energy neutrino (pp, $^7\text{Be}$) is main component. Other contributions CNO cycle. No direct observation yet.

Complete understanding of the Standard Solar Model or new physics?

Further understanding: Stellar evolution
KamLAND-II
Solar Neutrinos

BG in LS
$\approx 10^{-5}$

$^7\text{Be} \nu_e$

B.G. reduction requirement $\sim 1 \mu\text{Bq} / \text{m}^3$
<table>
<thead>
<tr>
<th>Background</th>
<th>now</th>
<th>goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{238}$U (by Bi-Po)</td>
<td>$3.5 \times 10^{-18}$g/g</td>
<td>OK!!</td>
</tr>
<tr>
<td>$^{238}$U (by $^{234}$Pa)</td>
<td>$O(10^{-15}$g/g)(Max.)</td>
<td>$10^{-18}$g/g</td>
</tr>
<tr>
<td>$^{232}$Th (by Bi-Po)</td>
<td>$5.2 \times 10^{-17}$g/g</td>
<td>OK!!</td>
</tr>
<tr>
<td>$^{40}$K</td>
<td>$2.7 \times 10^{-16}$g/g(max.)</td>
<td>$&lt; 10^{-18}$g/g</td>
</tr>
<tr>
<td>$^{210}$Pb</td>
<td>$\sim 10^{-20}$g/g</td>
<td>$5 \times 10^{-25}$g/g $\sim 1\mu$Bq/m$^3$</td>
</tr>
<tr>
<td>$^{85}$Kr, $^{39}$Ar</td>
<td>$^{85}$Kr =0.7Bq/m$^3$</td>
<td>$1\mu$Bq/m$^3$</td>
</tr>
<tr>
<td>$^{222}$Rn (after purification)</td>
<td>$^{238}$U = $3.5 \times 10^{-18}$g/g = $3.3 \times 10^{-8}$Bq/m$^3$</td>
<td>OK!! (1$\mu$Bq/m$^3$)</td>
</tr>
<tr>
<td>$^{222}$Rn (during purification)</td>
<td></td>
<td>$1$mBq/m$^3$</td>
</tr>
</tbody>
</table>
Reduction of $^{210}$Pb, $^{85}$Kr, $^{40}$K by distillation technique

KamLAND liquid scintillator

- $^{210}$Pb$^{n+}$
- PPO
- (organic $^{210}$Pb)
- Dodecane
- (organic $^{210}$Pb)
- Psedocumene
- $^{85}$Kr
- $^{222}$Rn

Boiling points

N$_2$ purge

Clean scintillator

Dirty scintillator

Reduction of $^{210}$Pb, $^{85}$Kr, $^{40}$K by distillation technique
~ liter scale system in a room

Distillation in ~ liter-system

<table>
<thead>
<tr>
<th>Radioactive nuclei</th>
<th>Reduction</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{40}$K</td>
<td>$3.8 \times 10^{-2}$ (PPO, $^{40}$K)</td>
<td>$10^{-1} \sim 10^{-2}$</td>
</tr>
<tr>
<td>$^{85}$Kr</td>
<td>$&lt; 1.3 \times 10^{-5}$ (Dodecane, Kr)</td>
<td>$10^{-5} \sim 10^{-6}$</td>
</tr>
<tr>
<td>$^{210}$Pb</td>
<td>$&lt; 7.6 \times 10^{-5}$ (Dodecane, $^{212}$Pb)</td>
<td>$10^{-4} \sim 10^{-5}$</td>
</tr>
<tr>
<td>$^{222}$Rn</td>
<td>$6.0 \times 10^{-4}$ (Dodecane, $^{222}$Rn)</td>
<td>$\sim 10^{-3}$</td>
</tr>
</tbody>
</table>
Vacuum

Seal Gas N2 (+ a few kPa)

Absorption + Exhaust

KamLAND Balloon

PC NP PPO

LS

C-11 D-41

E-24

C-32 D-31

Real system (~1.5 kilo liter/hour) has been installed onsite (2006 Aug.-Nov.)
Current status

Test bench
Pb: $3 \times 10^{-5}$  
Rn: $1 \times 10^{-5}$  
Kr: $<2 \times 10^{-6}$

N2 purge helps Rn reduction: $< \times 1/20 \text{ Rn}$

Valves etc. at mine tunnel were covered with Lucite case to avoid Rn leak.

Stable distillation and circulation (except PPO) for more than one month by the real system.

Light yeild (before/after distillation) was reproduced.
only PC(20)+NP(80)
# History of the distillation

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Start R&amp;D</td>
</tr>
<tr>
<td>2005 Spring</td>
<td>New purification area enlarged by blasting.</td>
</tr>
<tr>
<td>2006 Spring</td>
<td>New area set aside.</td>
</tr>
<tr>
<td>2006 Summer</td>
<td>New electricity supply ~1000kW</td>
</tr>
<tr>
<td>2006 Autumn</td>
<td>System installation</td>
</tr>
<tr>
<td>2006-07 Winter</td>
<td>Test distillation</td>
</tr>
<tr>
<td>2007 Now</td>
<td>Starting the distillation</td>
</tr>
<tr>
<td>2007 Soon</td>
<td>KamLAND-II</td>
</tr>
</tbody>
</table>
The KamLAND collaboration

Tohoku University, Japan,
California Institute of Technology, USA
University Bordeaux 1, France,
Drexel University, USA,
IHEP, China,
Kansas State University, USA,
Triangle Universities Nuclear Lab., USA,
University of Alabama, USA,
University of Hawaii, USA,
University of New Mexico, USA,
University of Tennessee, USA,
Lawrence Berkeley National Lab., USA,
Louisiana State University, USA,
Stanford University, USA