



KamLAND Liquid Scintillator and Gas Purification

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KamLAND Collaboration

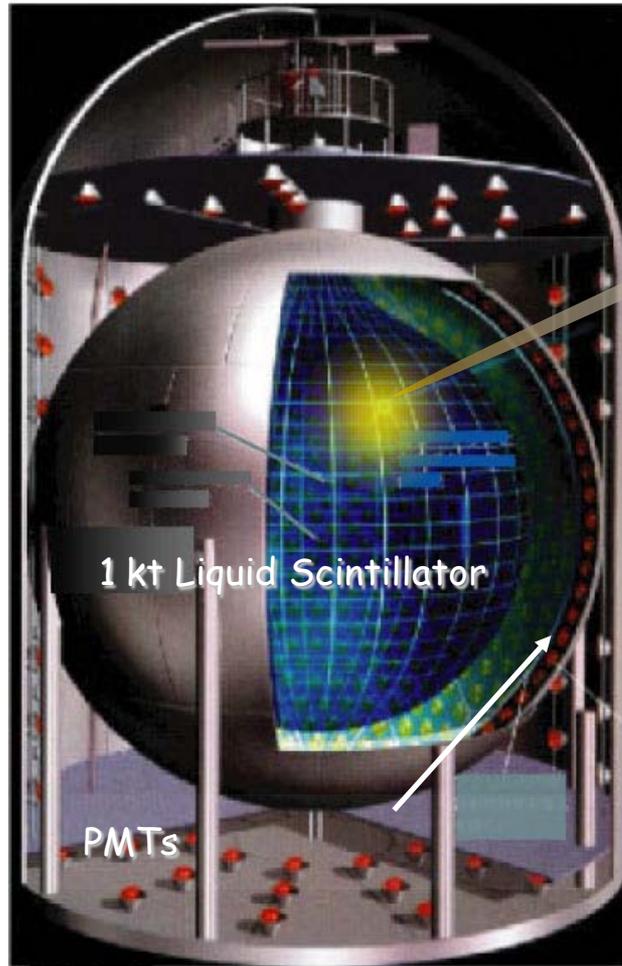
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KamLAND Detector

KAMioka Liquid scintillator Anti-Neutrino Detector



1 kt Liquid Scintillator

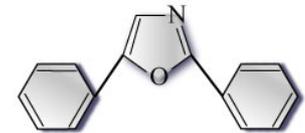
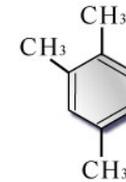
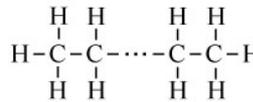
PMTs

KamLAND Detector

Inner Detector

• Liquid Scintillator (1000 tons)

- Ultra-pure ; U/Th $< 10^{-17}$ g/g



Dodecane (C₁₂H₂₆) : 80%

Pseudocumene : 20%
(1,2,4-Trimethyl Benzene)

PPO 1.36 g/l
(2,5-Diphenyloxazole)

• Plastic Balloon (13 m diameter)

• Mineral Oil : Inner buffer

- $\rho_{LS}/\rho_{MO} = 1.0004$

• PMTs

- 1325 of 17-inch and 554 of 20-inch
- Photo-coverage : 34% $\rightarrow \sim 500$ p.e./MeV

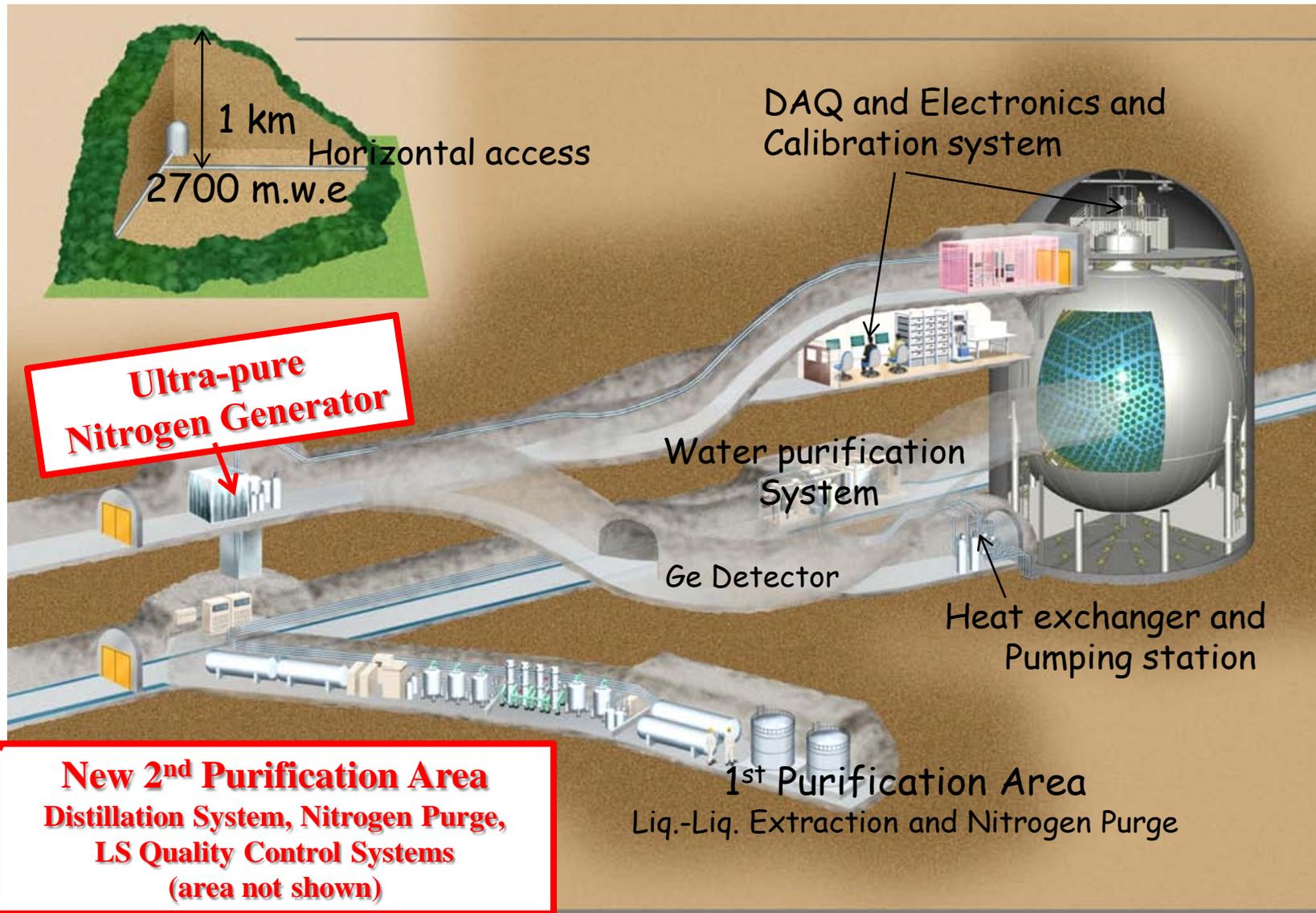
Outer Detector

• Water Cherenkov detector ; muon veto

• PMT

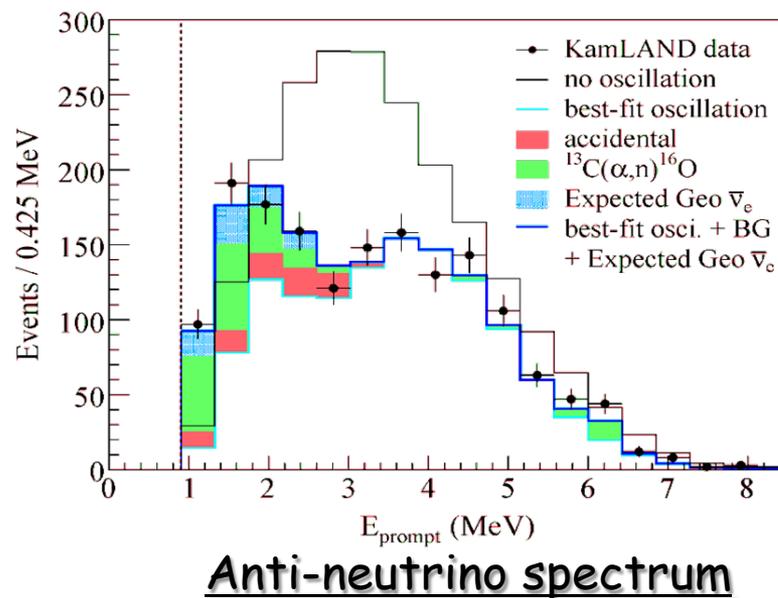
- 225 of 20-inch

KamLAND Underground Facility



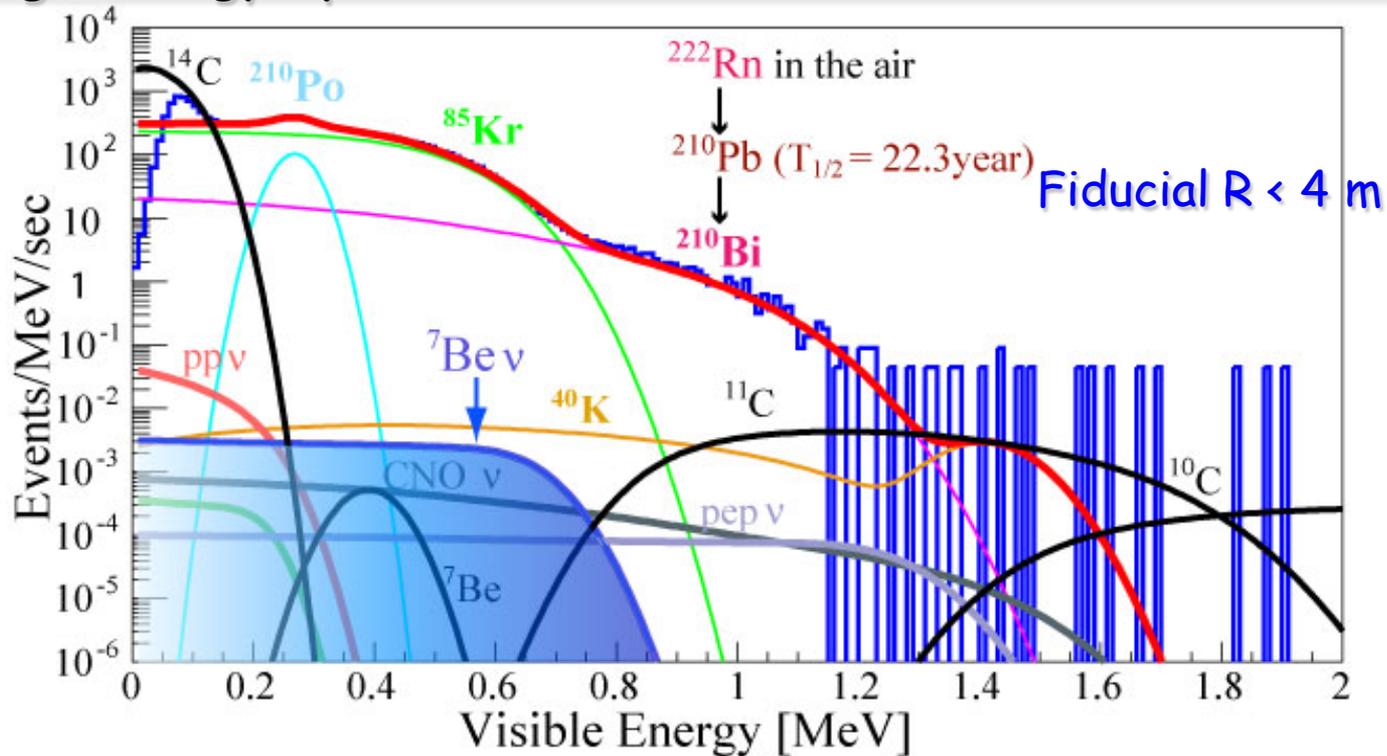
Motivation to the Low BG Phase

- Measurement of ${}^7\text{Be}$ solar neutrino flux.
- Put more stringent limits on CNO cycle contribution to the solar neutrino flux.
- Reduce ${}^{13}\text{C}(\alpha, n){}^{16}\text{O}$ background for reactor and geo- ν measurements, caused by ${}^{210}\text{Po}$ α -decay.



Internal Background of KamLAND

Single Energy Spectrum Observed in KamLAND **Before Purification**



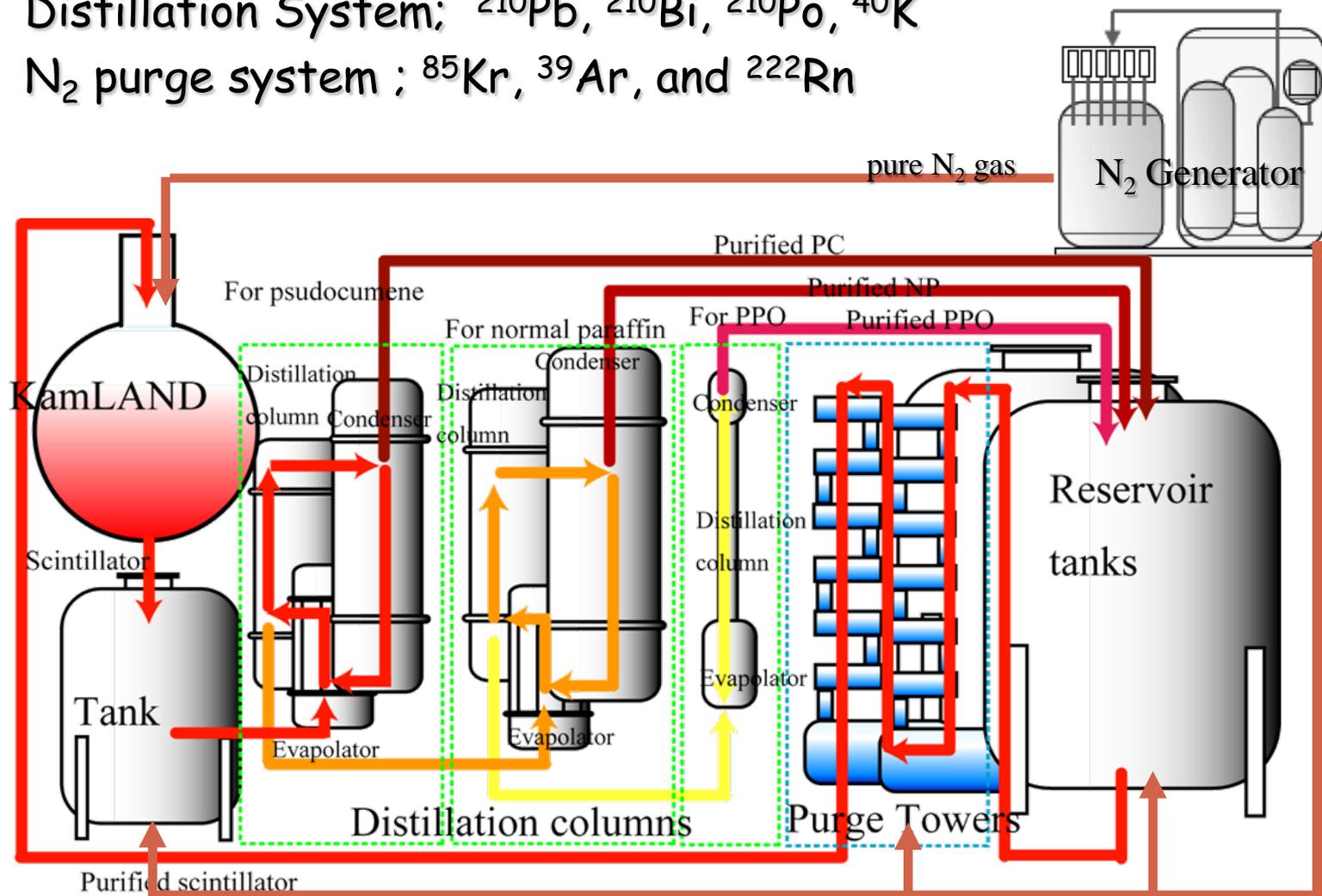
- Main sources of background in the range of ${}^7\text{Be}$ neutrino
 - ${}^{210}\text{Pb} (\rightarrow {}^{210}\text{Bi} \rightarrow {}^{210}\text{Po})$, ${}^{40}\text{K}$ ← by distillation
 - ${}^{85}\text{Kr}$ ← by N_2 purging
- pep/CNO neutrino ; ${}^{11}\text{C}$ ← by tagging neutron

Required Reduction for Solar Phase

	$T_{1/2}$	Activities (Before purif.)	Purification Goal	Required Reduction
^{210}Pb	22.3 y	40 mBq/m ³	1 $\mu\text{Bq}/\text{m}^3$	$10^{-4} \sim 10^{-5}$
^{40}K	10^9 y	$2 \cdot 10^{-16}$ g/g	10^{-18} g/g	10^{-2}
^{238}U	10^9 y	$3 \cdot 10^{-18}$ g/g	10^{-18} g/g	OK
^{232}Th	10^{10} y	$5 \cdot 10^{-17}$ g/g	10^{-16} g/g	OK
^{85}Kr	11 y	400 mBq/m ³	1 $\mu\text{Bq}/\text{m}^3$	$10^{-5} \sim 10^{-6}$
^{222}Rn	3.8 d		$< 10 \mu\text{Bq}/\text{m}^3$	---

Concept of New Purification System

- Online purification with the flow rate $\sim 1 \text{ m}^3/\text{h}$.
- Distillation System; ^{210}Pb , ^{210}Bi , ^{210}Po , ^{40}K
- N_2 purge system ; ^{85}Kr , ^{39}Ar , and ^{222}Rn



Pure Nitrogen Generator

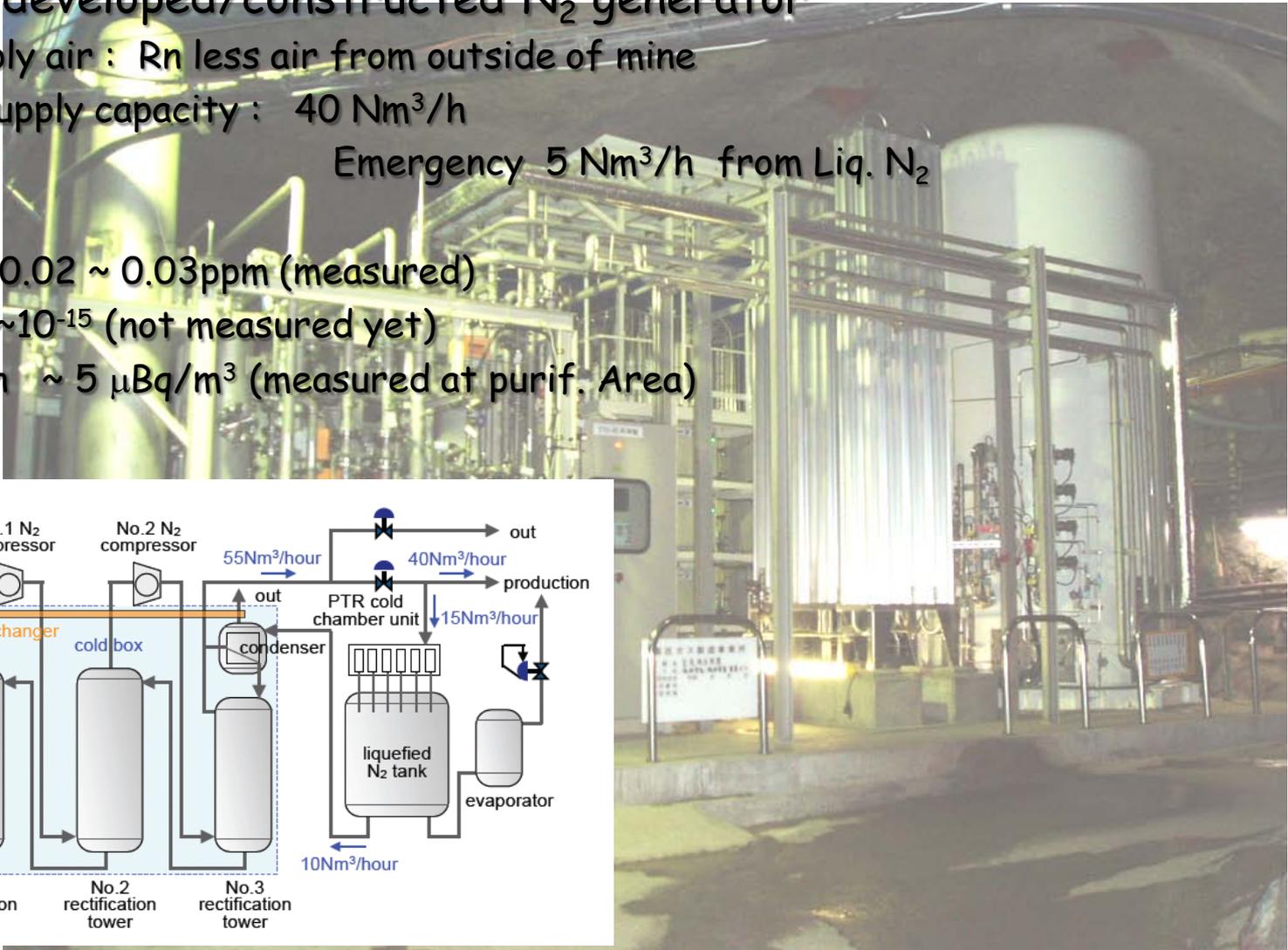
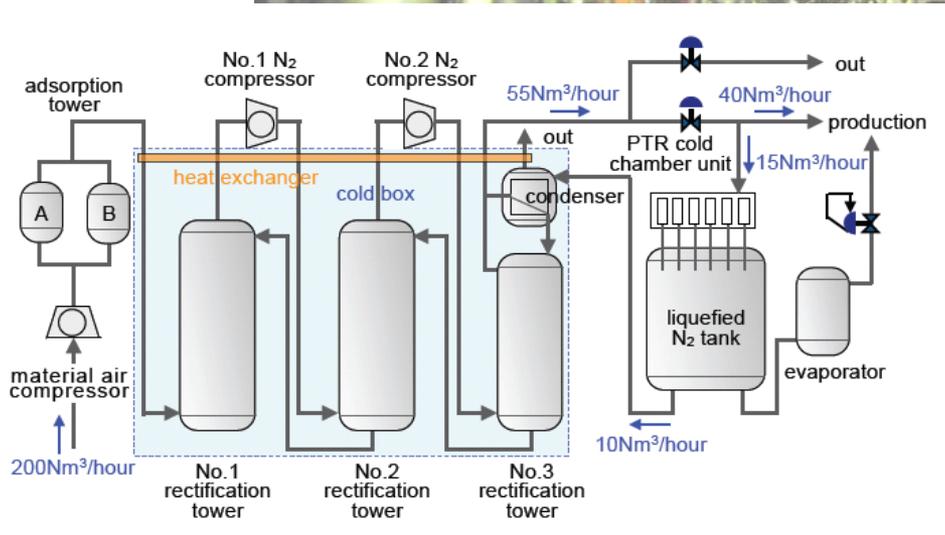
- Newly developed/constructed N₂ generator

- Supply air : Rn less air from outside of mine
- N₂ supply capacity : 40 Nm³/h

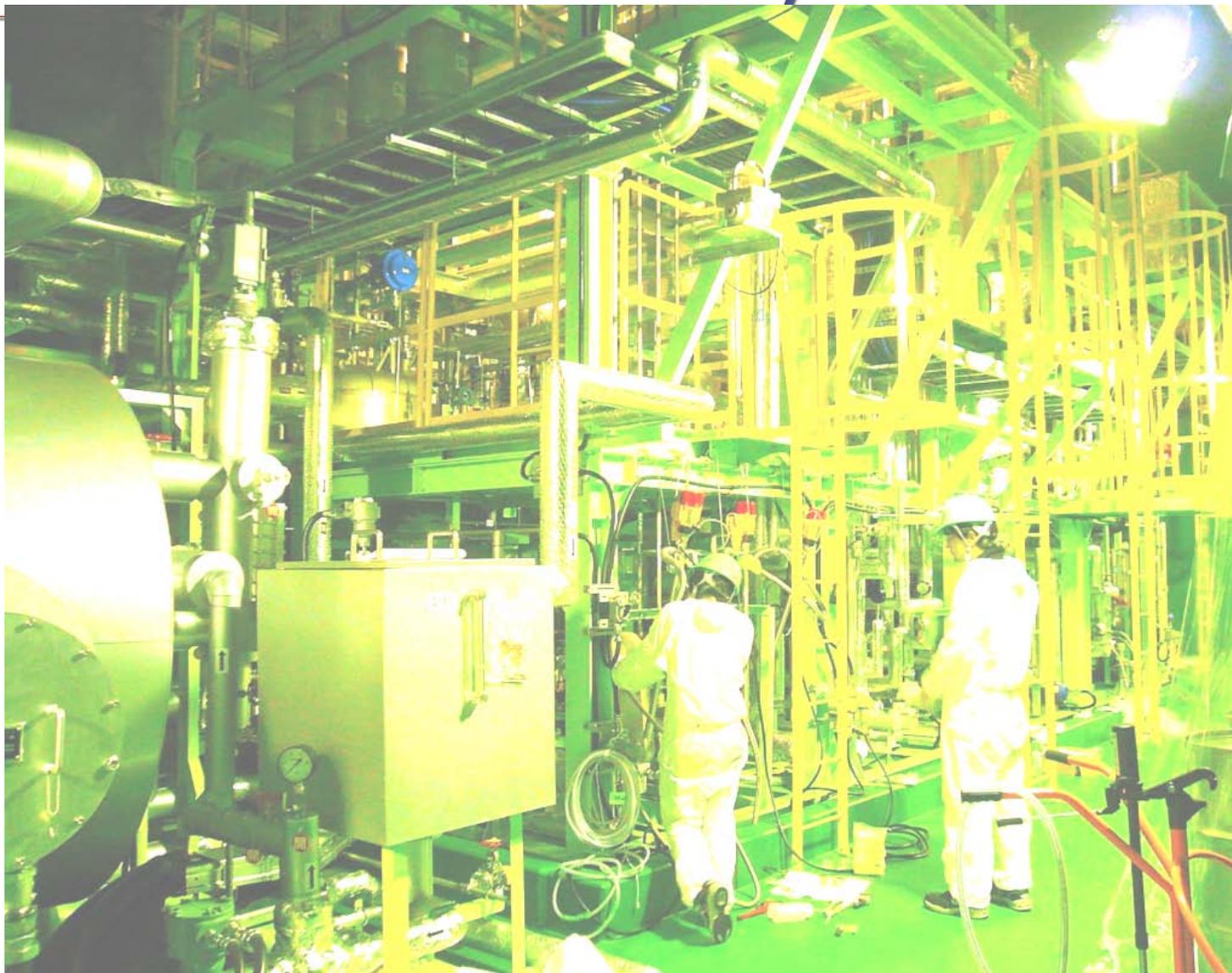
Emergency 5 Nm³/h from Liq. N₂

- Purity

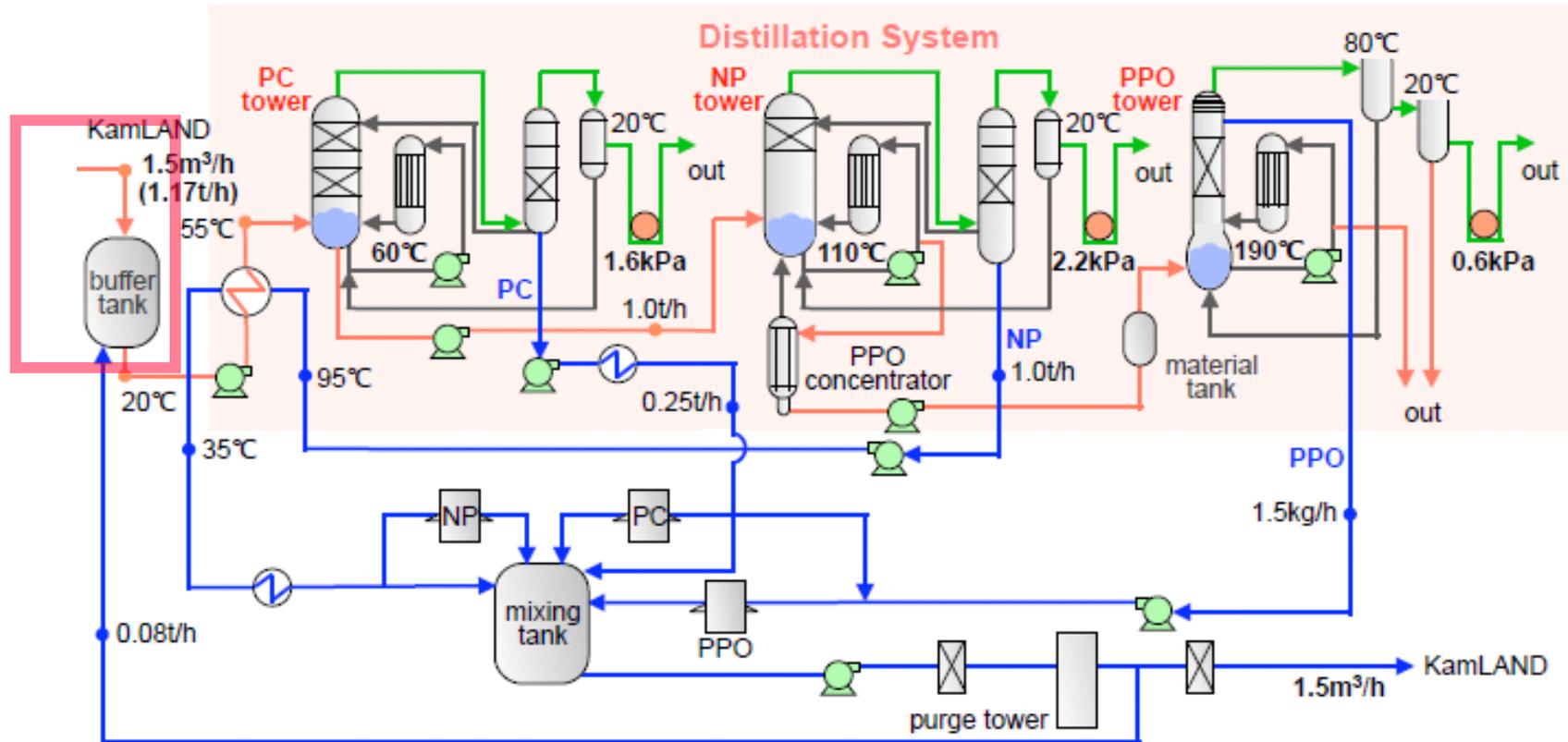
- Ar 0.02 ~ 0.03ppm (measured)
- Kr ~10⁻¹⁵ (not measured yet)
- ²²²Rn ~ 5 μBq/m³ (measured at purif. Area)



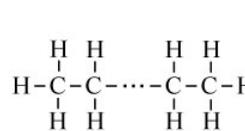
Distillation System



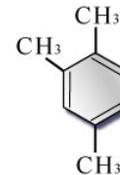
Online Purification Process(1)



- Liquid scintillator(LS) is fed into small buffer tank (2 m³) from KamLAND.
- Different boiling point



Dodecane (C₁₂H₂₆) : 80%

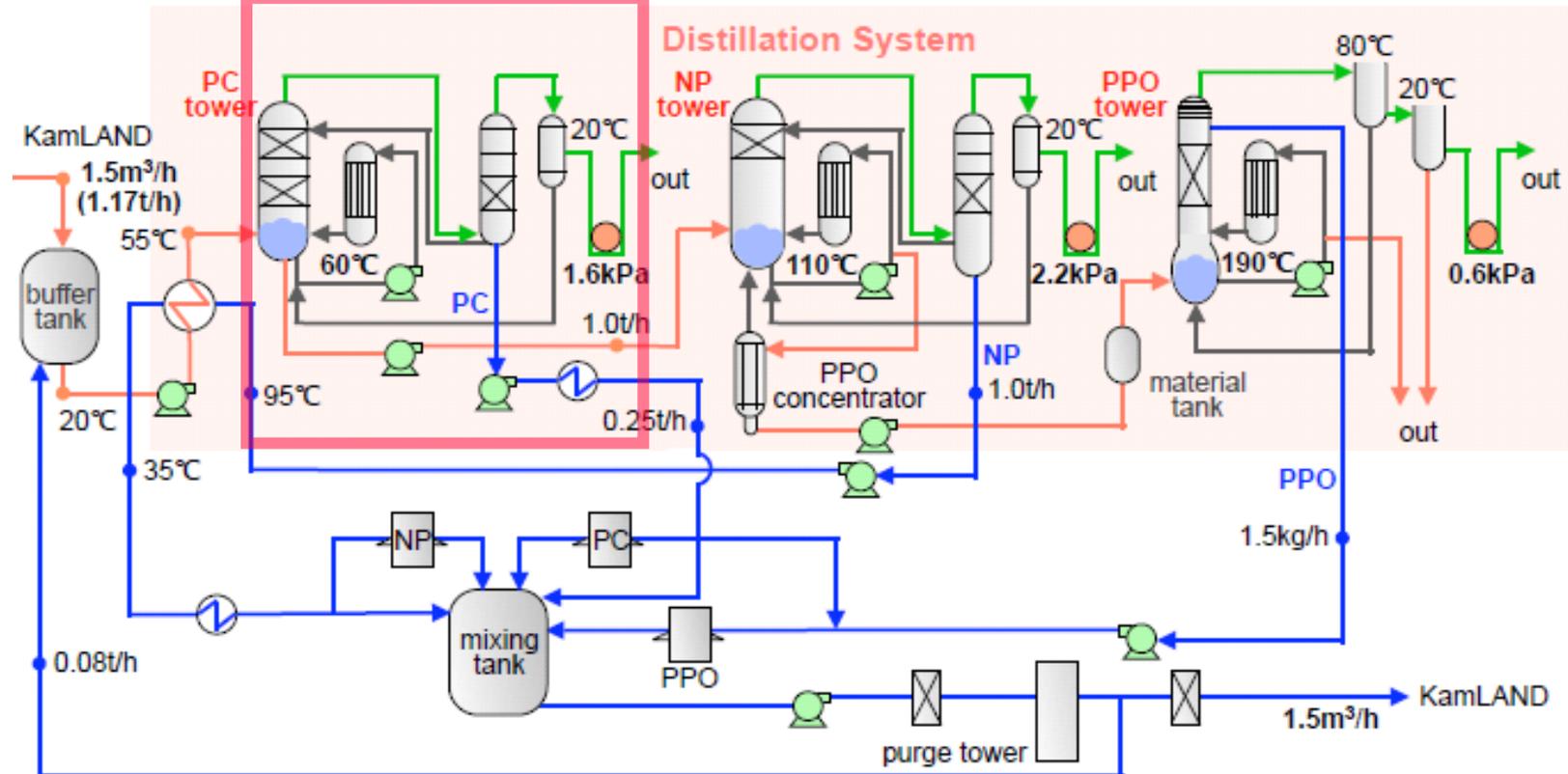


Pseudocumene : 20%
(1,2,4-Trimethyl Benzene)



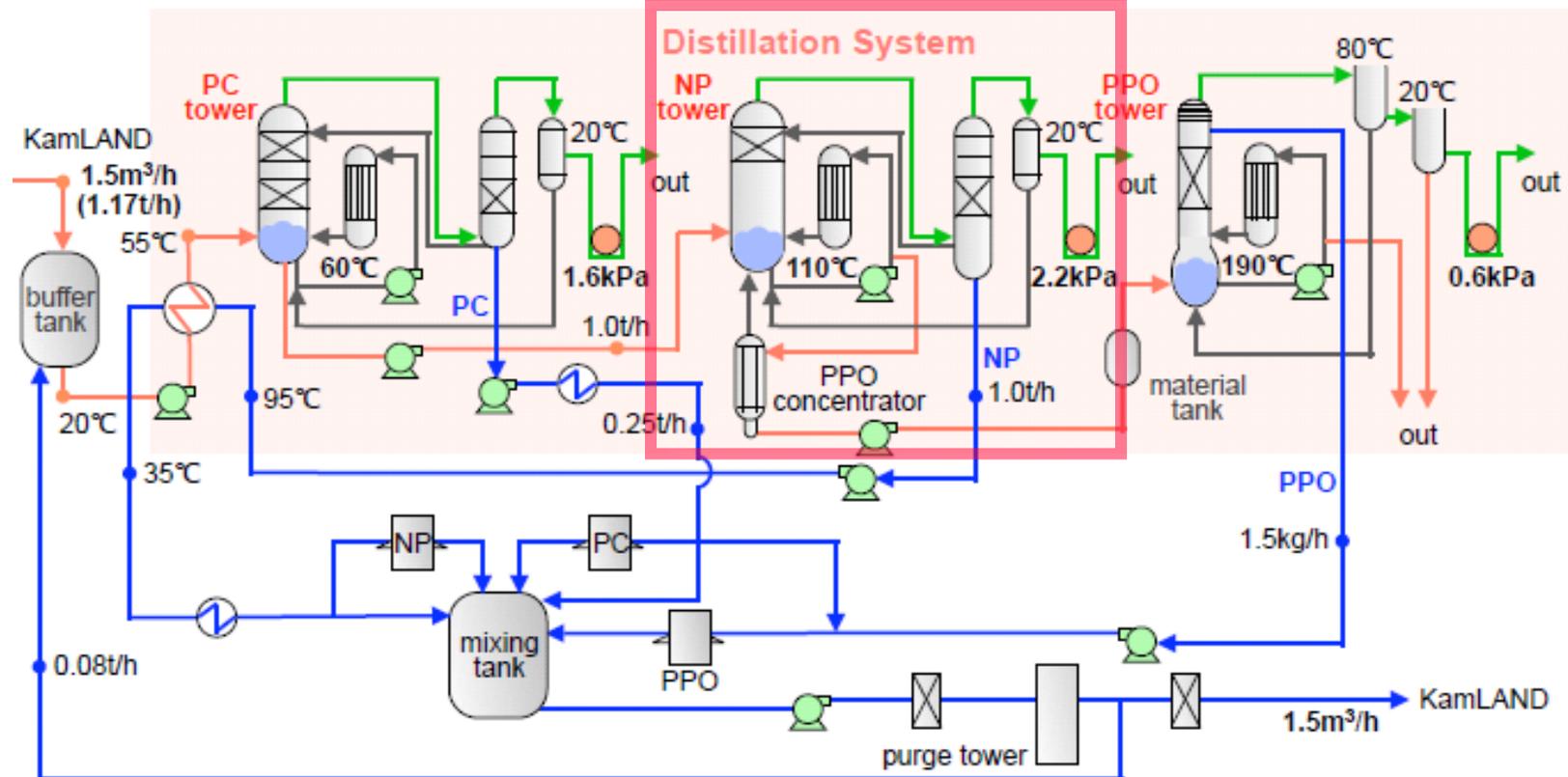
PPO : 1.5 g / l
(2,5-Diphenyloxazole)

Online Purification Process(2)



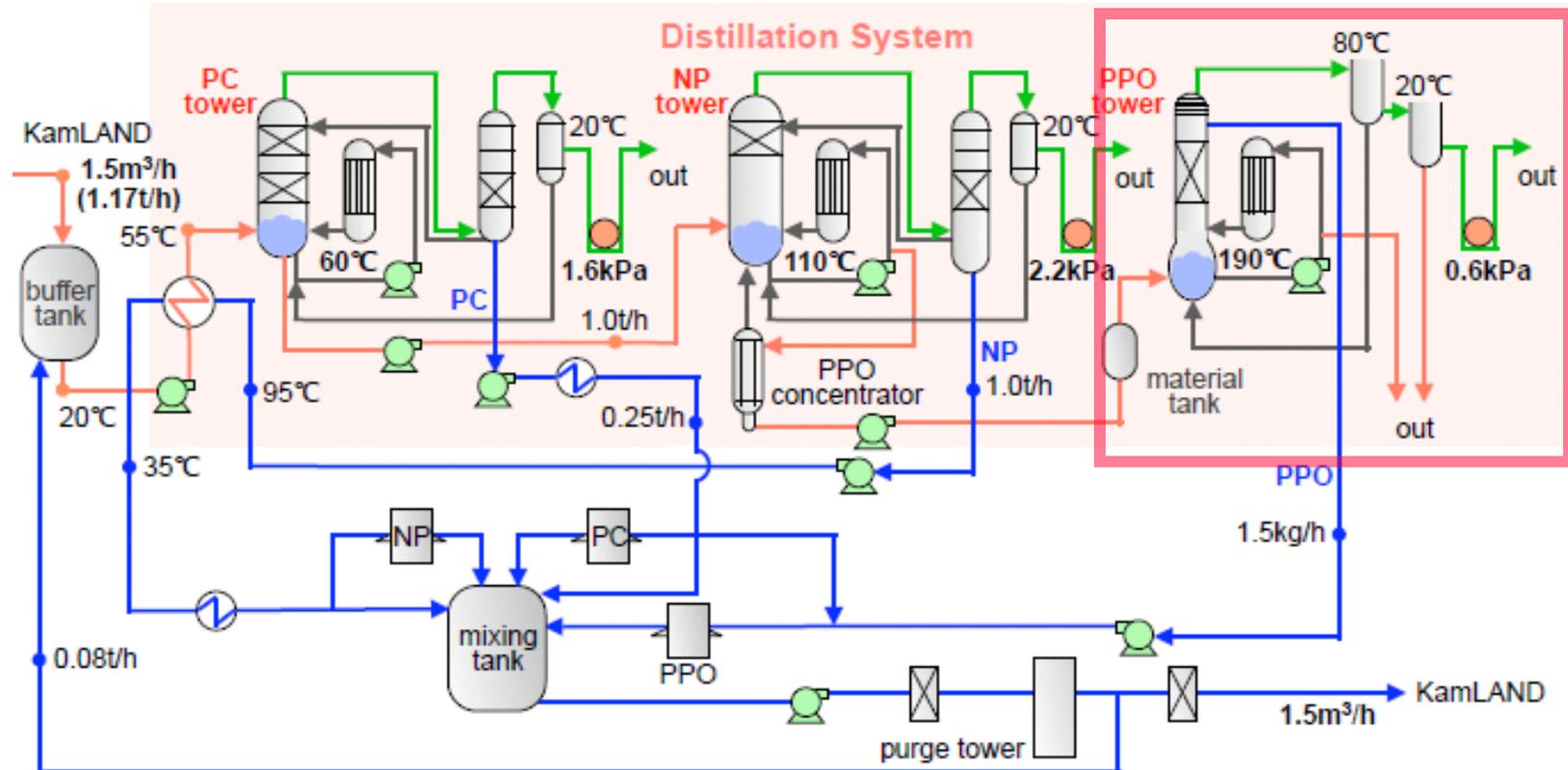
- Pseudocumene(PC) is distilled firstly
 - ◆ Operating pressure 2 kPa.
 - ◆ Boiling point ~ 60°C
- Rest at the bottom of PC tower → Dodecane + PPO
 - ◆ → send to next tower

Online Purification Process(3)



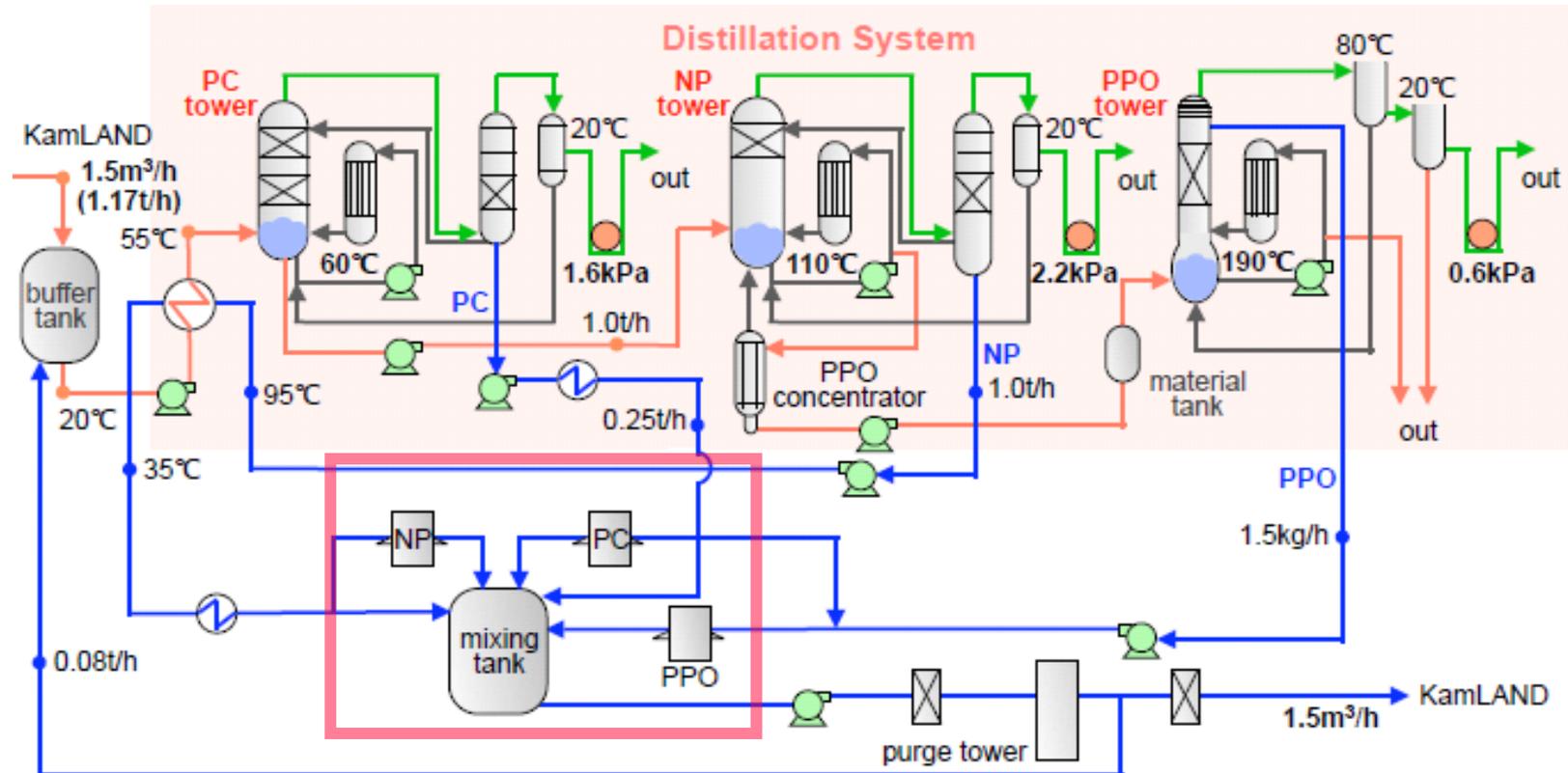
- Dodecane(NP) is distilled secondly.
 - ◆ Operating pressure ~2 kPa.
 - ◆ Boiling point ~ 100°C
- Rest at the bottom of NP tower → Dodecane + PPO(little concentrated)
 - ◆ → send to PPO concentrator (~140°C under 2 kPa), NP is evaporated back to NP tower.

Online Purification Process(4)



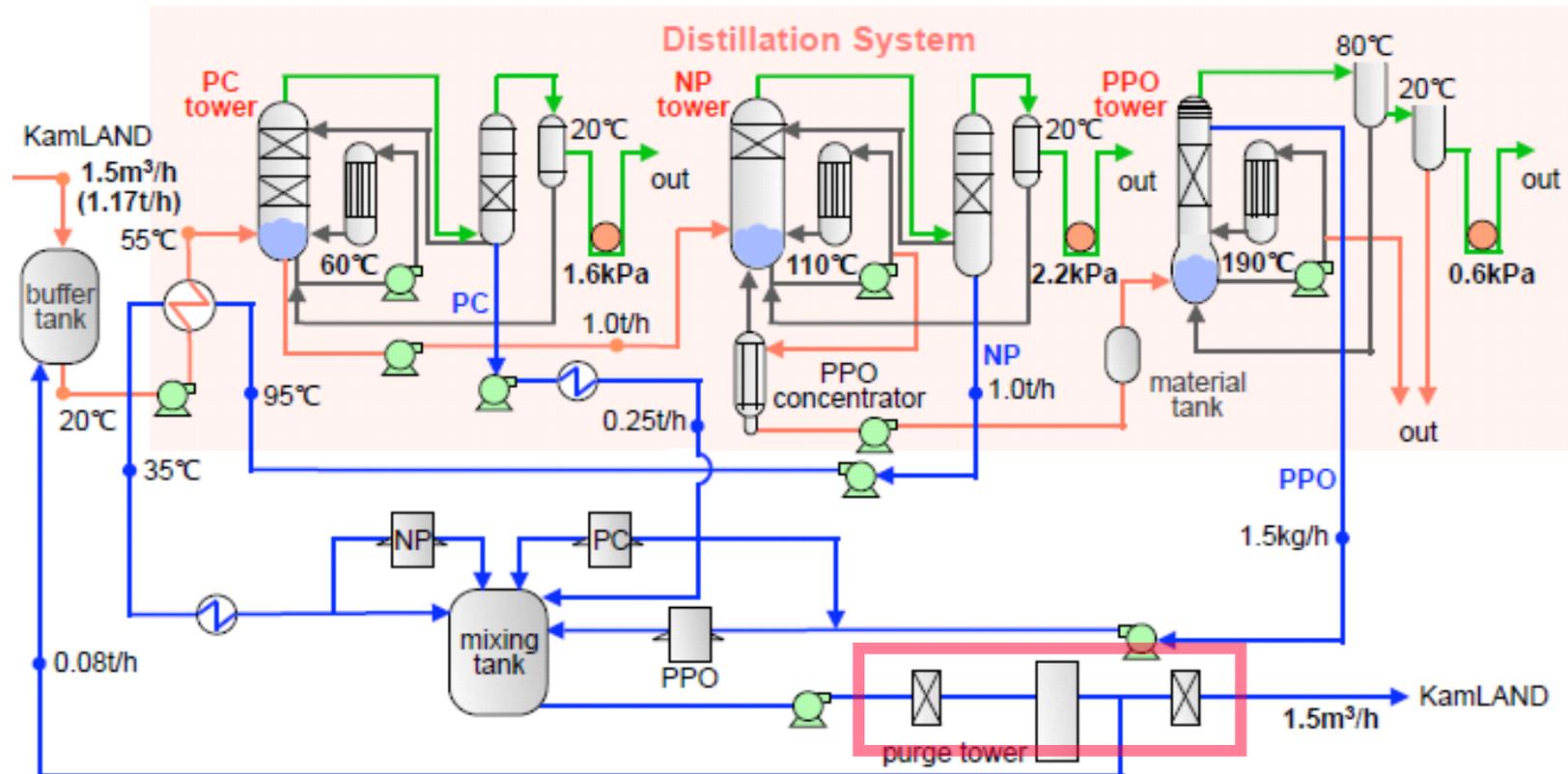
- PPO is distilled finally.
 - Operating pressure ~0.3(2nd Phase) ~ 0.6(1st Phase) kPa.
 - Boiling point ~ 160 ~ 190°C
- Rest at the bottom of PPO tower → Exhaust

Online Purification Process(5)



- LS is mixed (blended) with distilled PC, NP, and PPO.
- Temperature sensor and Density meter
 - PC and NP mixture is adjusted by pre-small tank.
 - PPO is mixed with PC ~ 10 wt%, then fed into mixture tank.

Online Purification Process(6)



● Purging by pure N₂ gas

- Operating pressure ~ 40 kPa
- N₂ flow rate ~ 30 Nm³/h
- Series of "Gas - Liq. Mixer", and "Gas-Liq. Separator"

Quality Control During Purification

- Purpose is to insure high levels of purification and prevent re-contaminating after purification procedure
- **^{39}Ar and ^{85}Kr measurement system** gives us sensitivity to low concentrations ($10\ \mu\text{Bq}/\text{m}^3$) by using a cold trap and RGA.
 - Assumes secular equilibrium with natural isotopic abundances.
- **^{222}Rn measurements.** Two devices
 - α counting by electrostatic collection method after trapping Rn
 - $\sim 1\ \text{m}^3$ scintillation detector to measure ^{214}Bi -Po coincidences (miniLAND)
 - Sensitivities $\sim 10\ \mu\text{Bq}/\text{m}^3$
- **Optical Properties**
 - Light Attenuation Length
 - Light Yield
- **Density** ; Accuracy $\sim 10^{-5}$
- **PPO concentration**
 - Gas Chromatography

Progress of Purification(1)

● 1st Purification Phase :

- May/12/2007 ~ Aug/01/2007
- Purified ~ 1500 m³ from the top
- Purification was stopped, because mining company was blasting for a new cavity.

● Problems in 1st Phase:

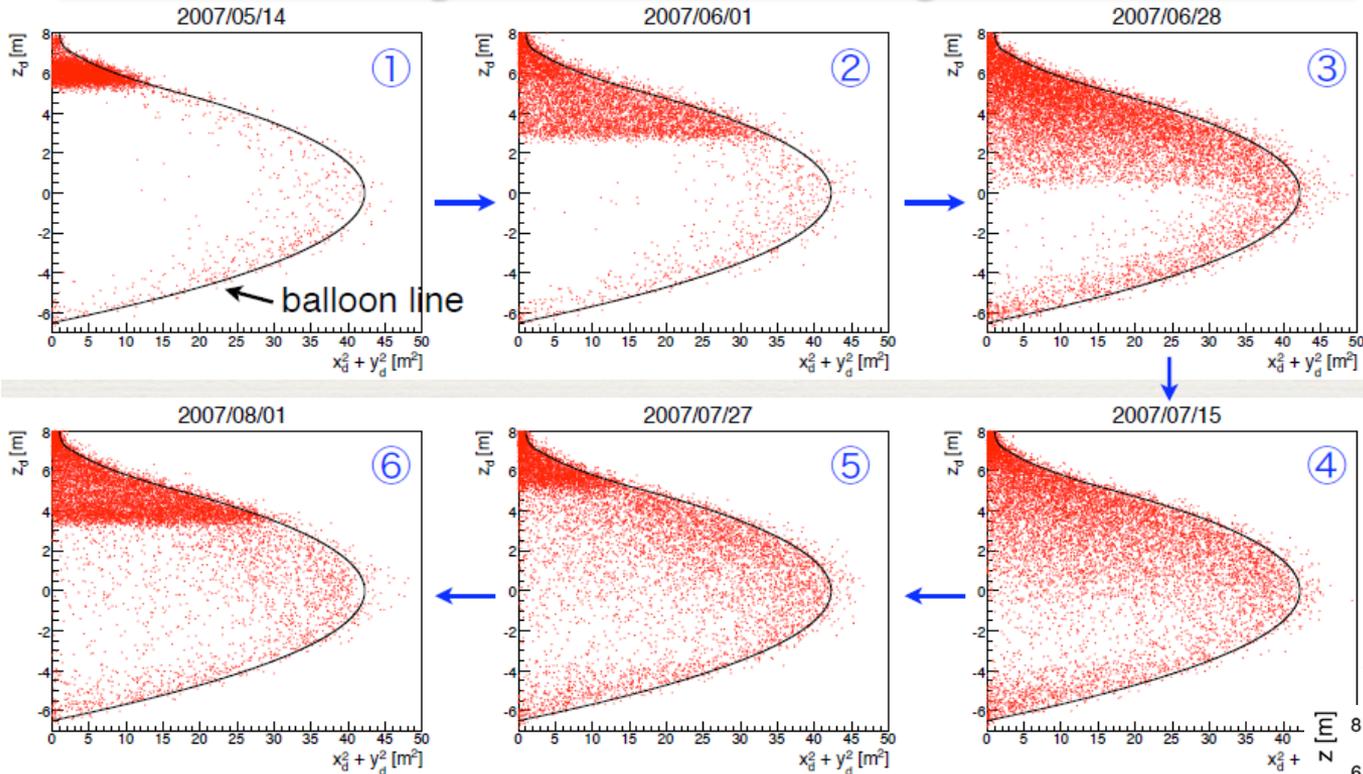
- Mixing was seen in Bi-Po signal.
- 10 % loss in light yield seen after one volume transfer
- The activities are still high for ⁷Be and pep/CNO ν.
- Worse reduction for ⁸⁵Kr
→ considered due to the leak in the chimney.

● 2nd Purification Phase :

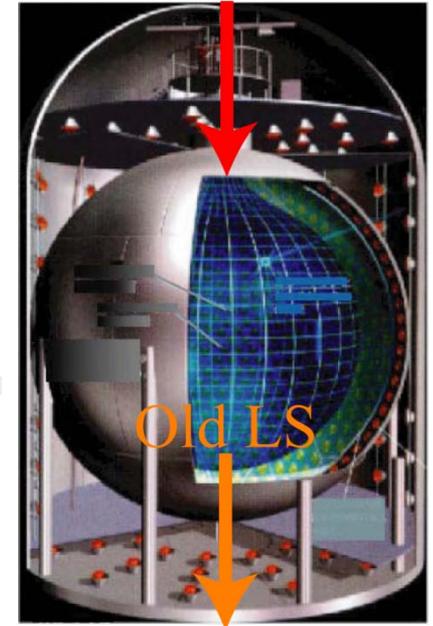
- Jun/16/2008 to Feb/06/2009
- Three full volume transfers were performed.
- Changed to bottom filling after completing first volume transfer.

Online Purification

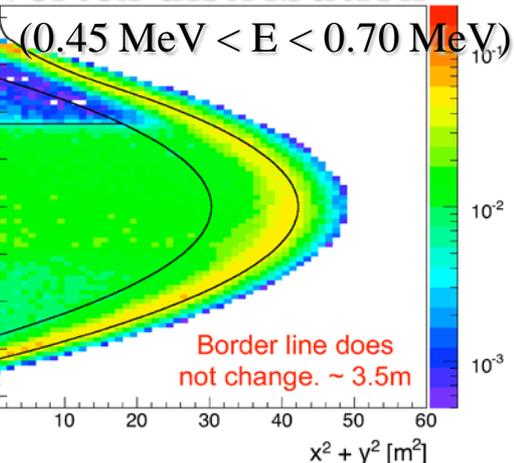
Online monitoring $^{214}\text{Bi-Po}$ (^{222}Rn daughter) Distribution



Purified LS



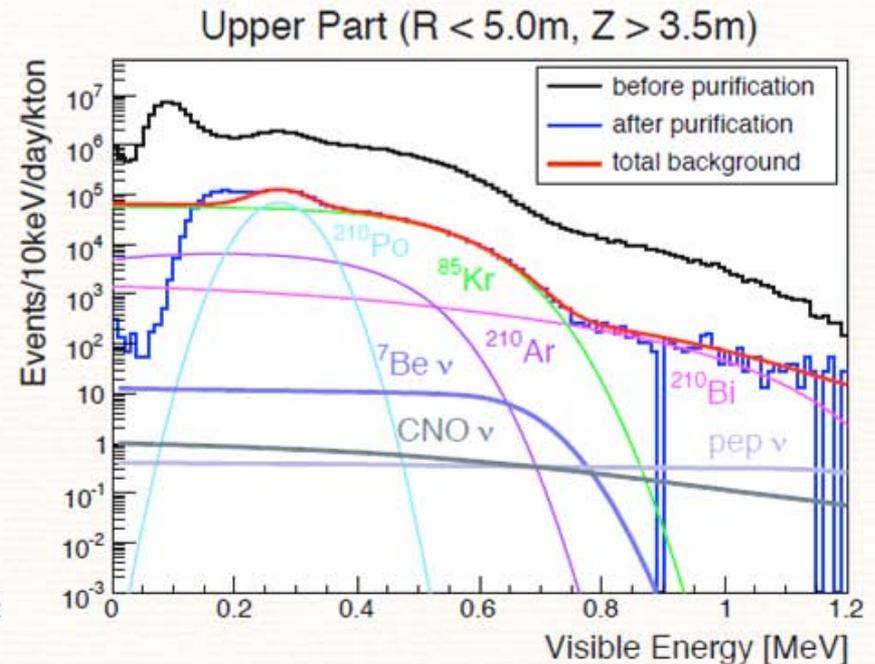
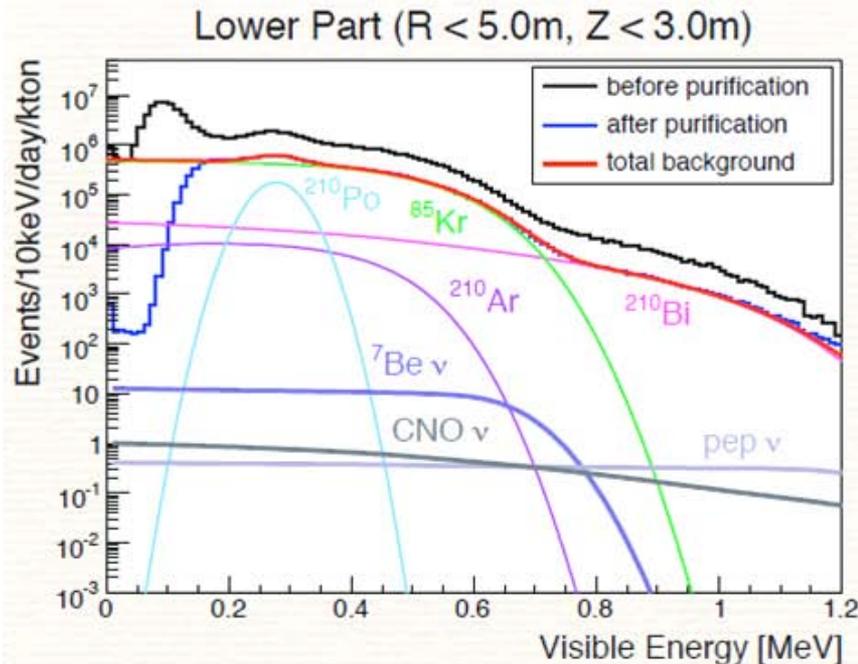
Vertex distribution



- ① Starting purification
- ② Keeping boundary
- ③ Dropping purified LS along balloon surface
- ④ Mixing purified LS with old LS
- ⑤ Re-making new boundary with lighter LS
- ⑥ Stopping 1st purification phase

Results of 1st Purification

	²¹⁰ Bi	⁸⁵ Kr	³⁹ Ar	²¹⁰ Po	⁴⁰ K
Before	42 ⁺⁸ ₋₆	508 ⁺¹⁹ ₋₃₄	18 ⁺³⁸ ₋₁₈	43 ⁺¹ ₋₂	44±4μBq/m ³
After (top)	0.2±0.1	14 ⁺¹ ₋₄	0 ⁺⁵ ₋₀	9±1	-
(low)	10±1	185 ⁺¹ ₋₂	0 ⁺² ₋₀	14±1	13±1μBq/m ³
Reduction (top)	(4.8±2.6)×10 ⁻³	(2.8±0.8)×10 ⁻²	-	0.21±0.03	-
(low)	0.24±0.05	0.36±0.02	-	0.33±0.03	0.29±0.03



Accomplishments

- **Online purification was accomplished by the 2nd purification.**
 - Offline data analysis is being progressed.
 - BG reduction ; $10^{-4} \sim 10^{-5}$ in the ${}^7\text{Be}-\nu$ range
- **(α, n) background was reduced.**
 - \rightarrow negligible background for geo- ν measurement.
- **${}^8\text{B}$ solar- ν measurement**
 - Threshold energy pushing down to 3 MeV.

Summary

- New purification system was constructed.
 - Distillation & N₂ purge.
 - Pure N₂ gas generator
 - Online purification was performed.
- 1st and 2nd phase of purification has been accomplished.
 - Offline data analysis is being progressed.
 - Reduced BG ; 10⁻⁴ ~ 10⁻⁵ in the ⁷Be- ν range
 - (α ,n) background was reduced.
 - negligible background for geo- ν measurement.
 - ⁸B solar- ν measurement
 - Threshold energy pushing down to 3 MeV.
- Data taking will be continued till ~Feb./2011
 - Move to the next phase ; $0\nu\beta\beta$ of ¹³⁶Xe