

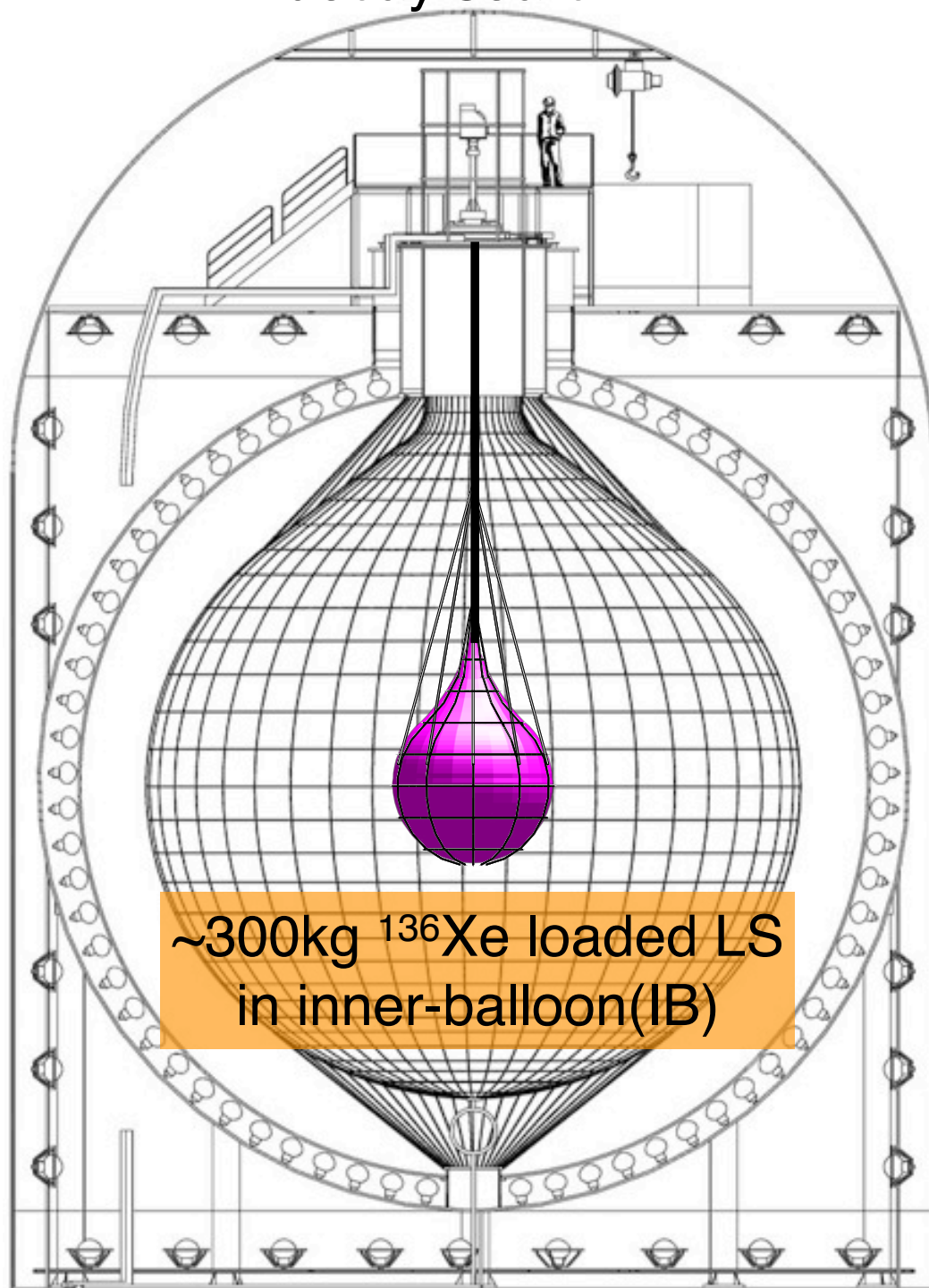
Purification of KamLAND-Zen Liquid Scintillator

LRT2013 - IV Workshop in Low Radioactive Techniques
2013/4/10-12

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Tohoku University
H. Ikeda

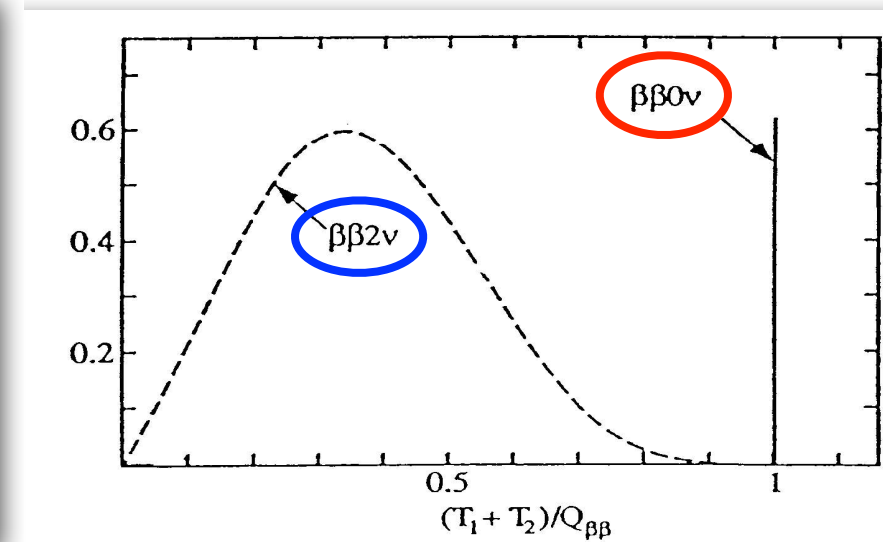
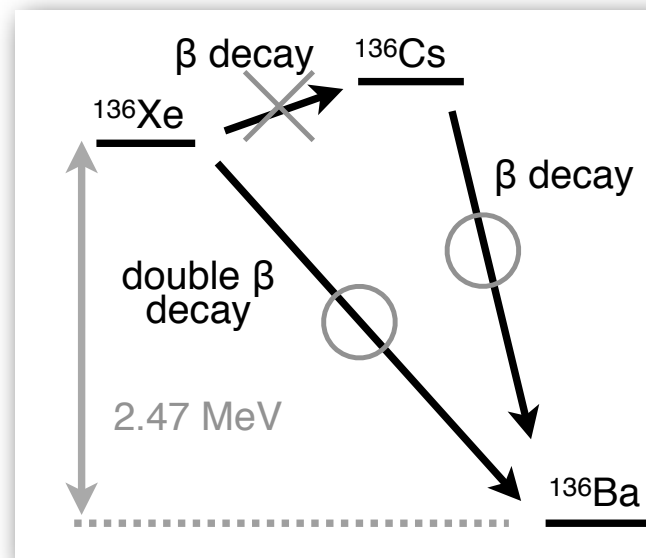
KamLAND-Zen Experiment

Kamioka Liquid-scintillator
Anti-Neutrino Detector
Zero neutrino double beta
decay search



Using ultra pure 1 kton KamLAND detector as active shield. [$U < 3.5 \times 10^{-18}$ g/g, $Th < 5.2 \times 10^{-17}$ g/g]

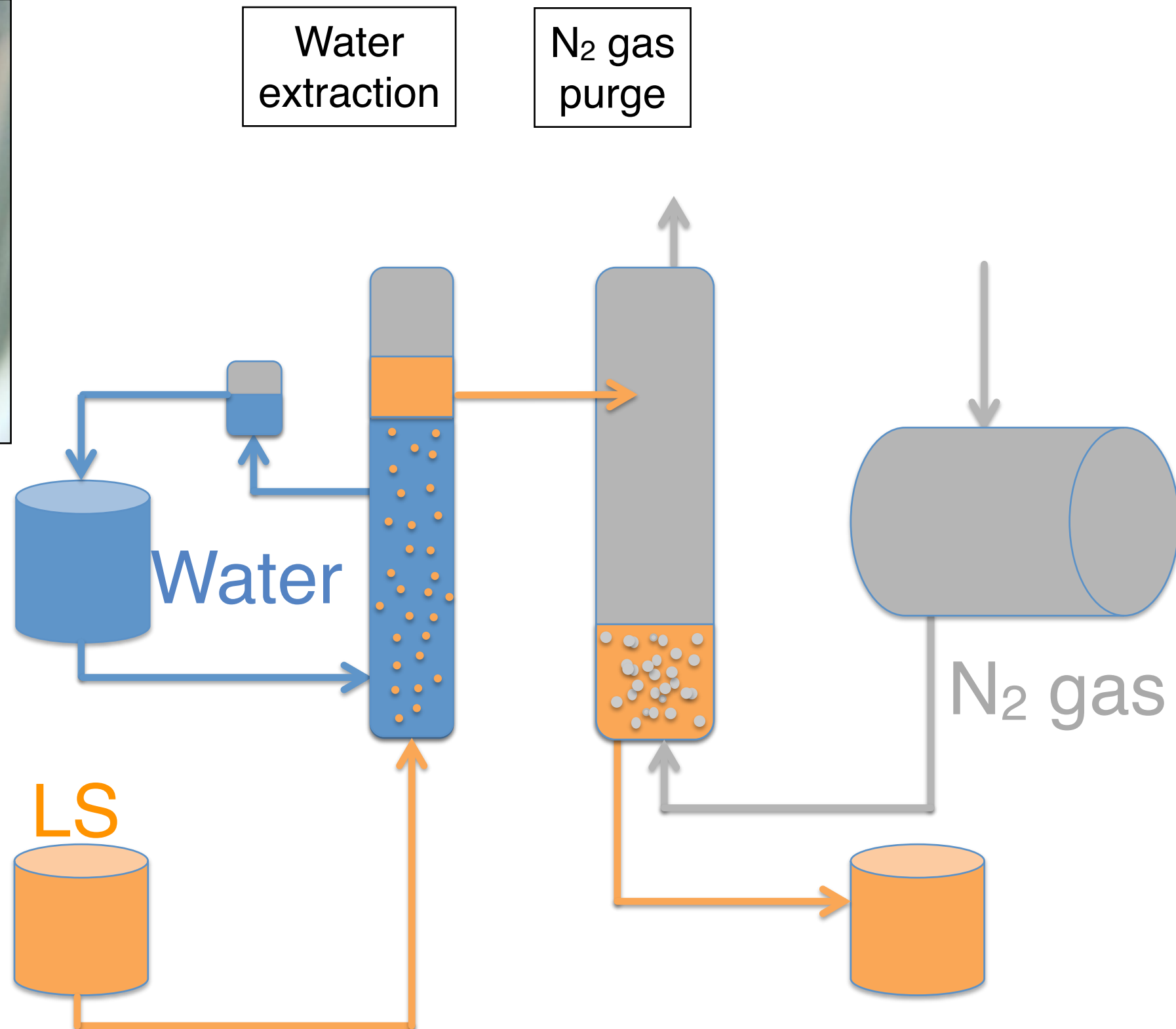
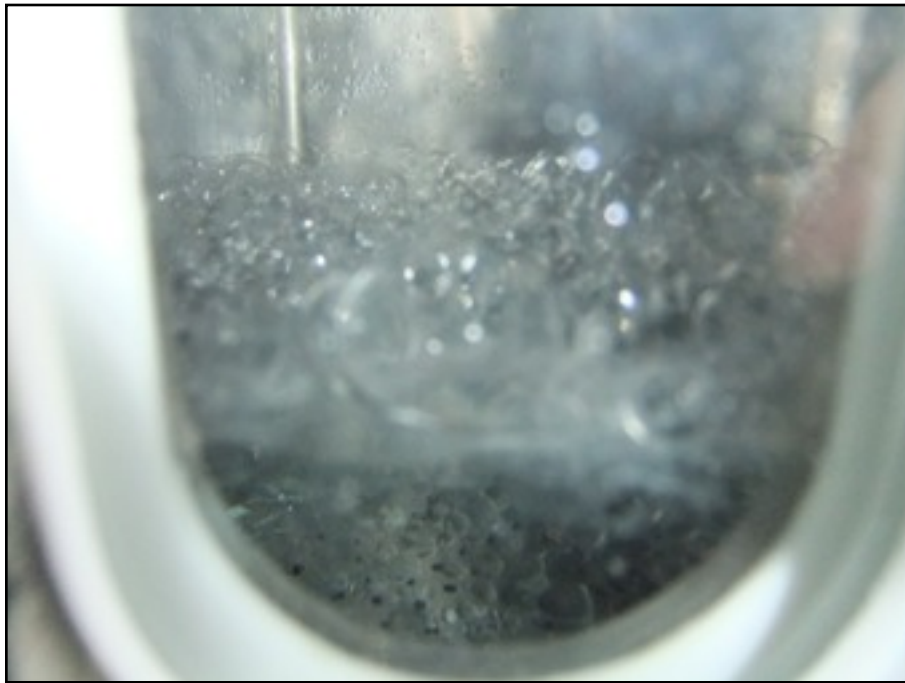
91% enriched ^{136}Xe gas dissolved LS in 3.08m diameter 25 μm nylon film inner balloon.



New **Xe system** and **inner-balloon** are constructed.
Use KamLAND **water extraction** system and **distillation** system to purify LS in inner balloon.

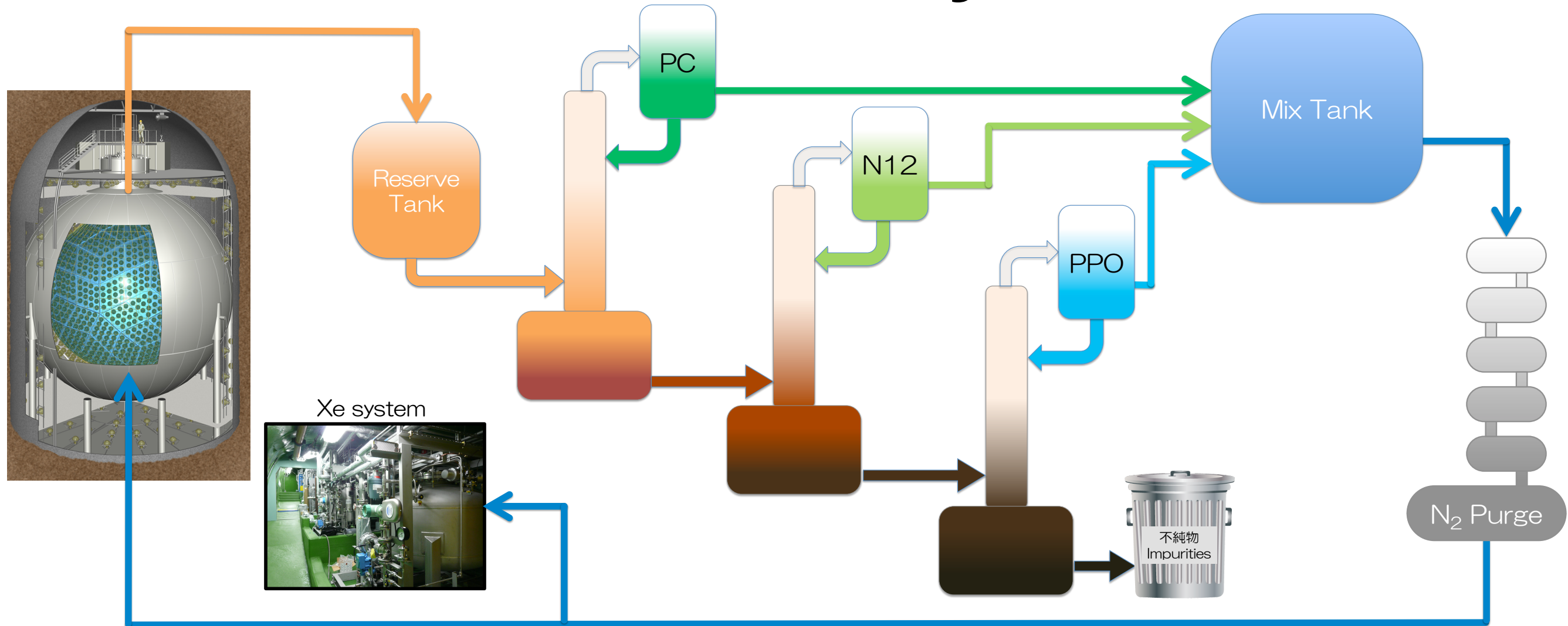
Start normal DAQ @ 2011/9/27
Energy resolution: $6.6\%/\sqrt{E[\text{MeV}]}$
Vertex resolution: $15\text{cm}/\sqrt{E[\text{MeV}]}$

Water Extraction System



- Constructed with KamLAND detector.
- Used for KamLAND LS purification at installation.
- After ultra pure N₂ generator construction, disposable N₂ gas is used for purge.

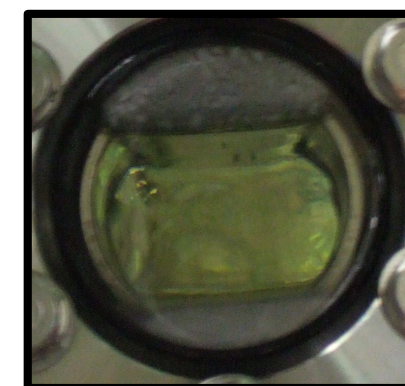
Distillation System



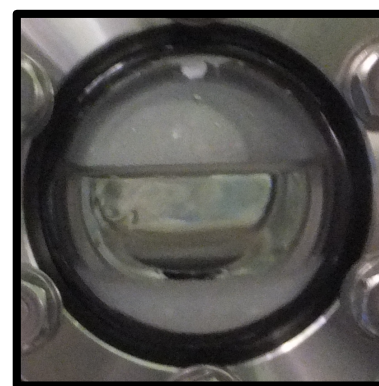
- Constructed for ^7Be solar neutrino detection.
- Two times distillation campaign at 2007 and 2008 done and U-series and Kr were removed dramatically.



PPO distillation

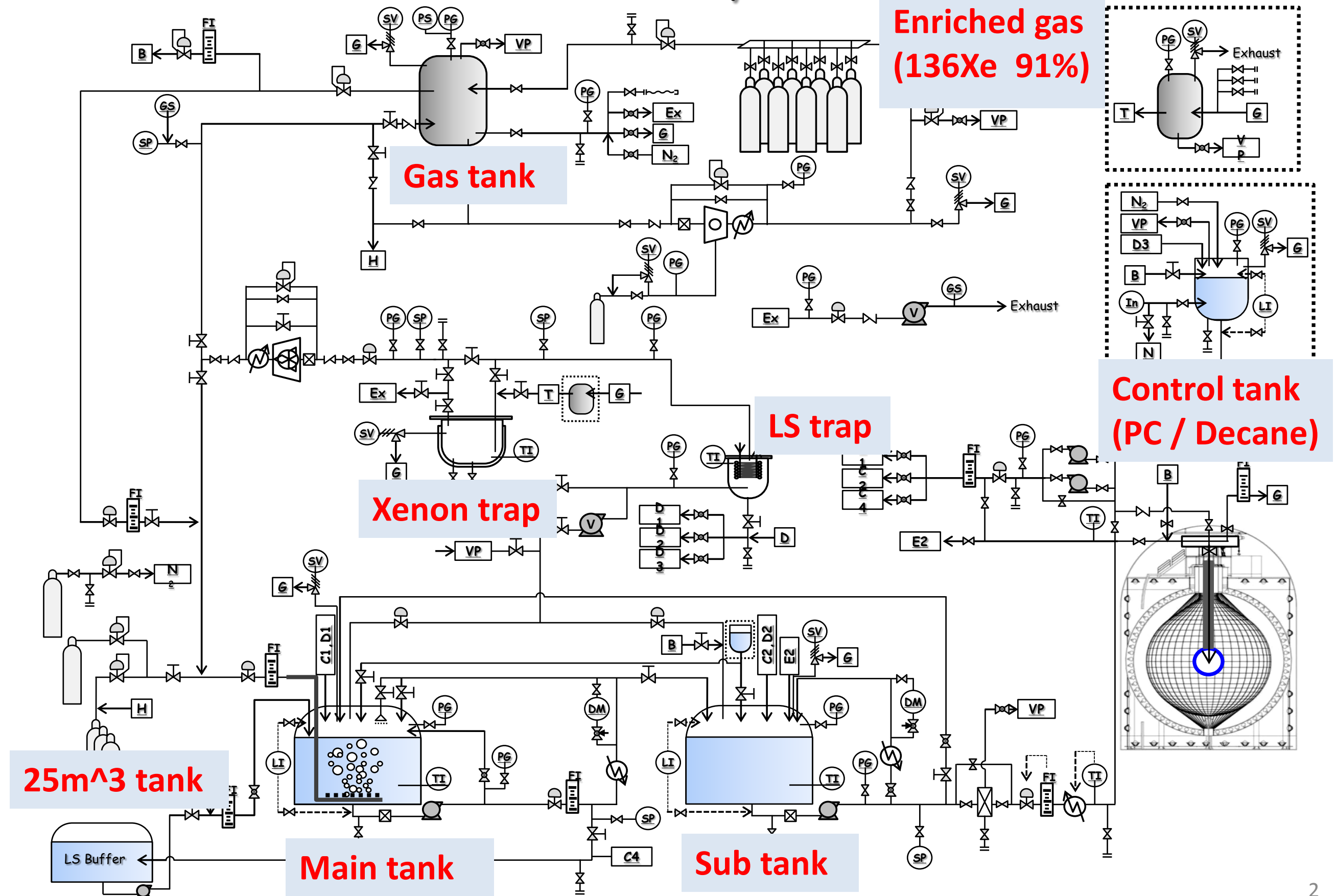


before



after

XENON system



Xenon room



Bottles



Main tank



sub tank



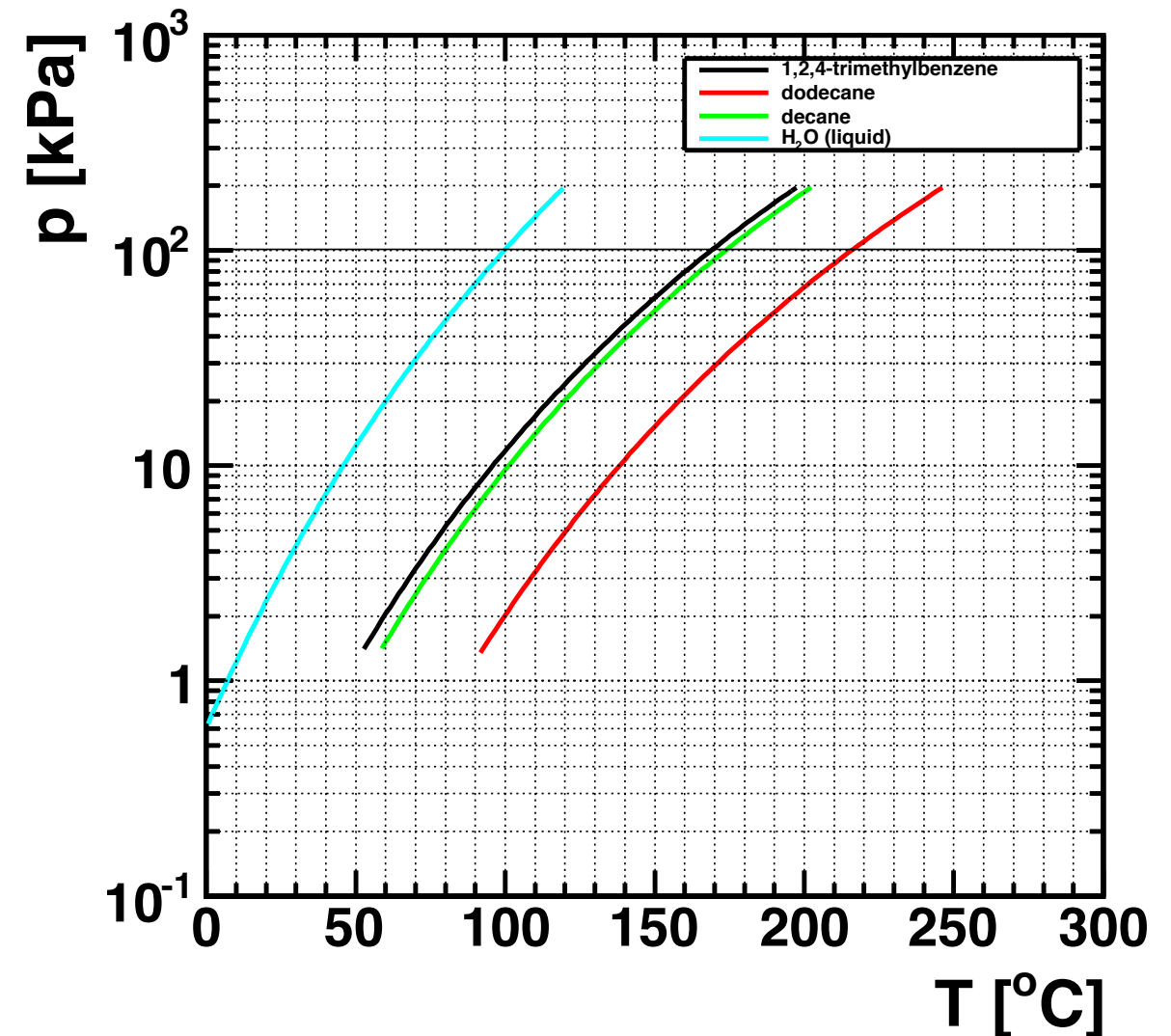
LS trap / Xenon trap



Operation system

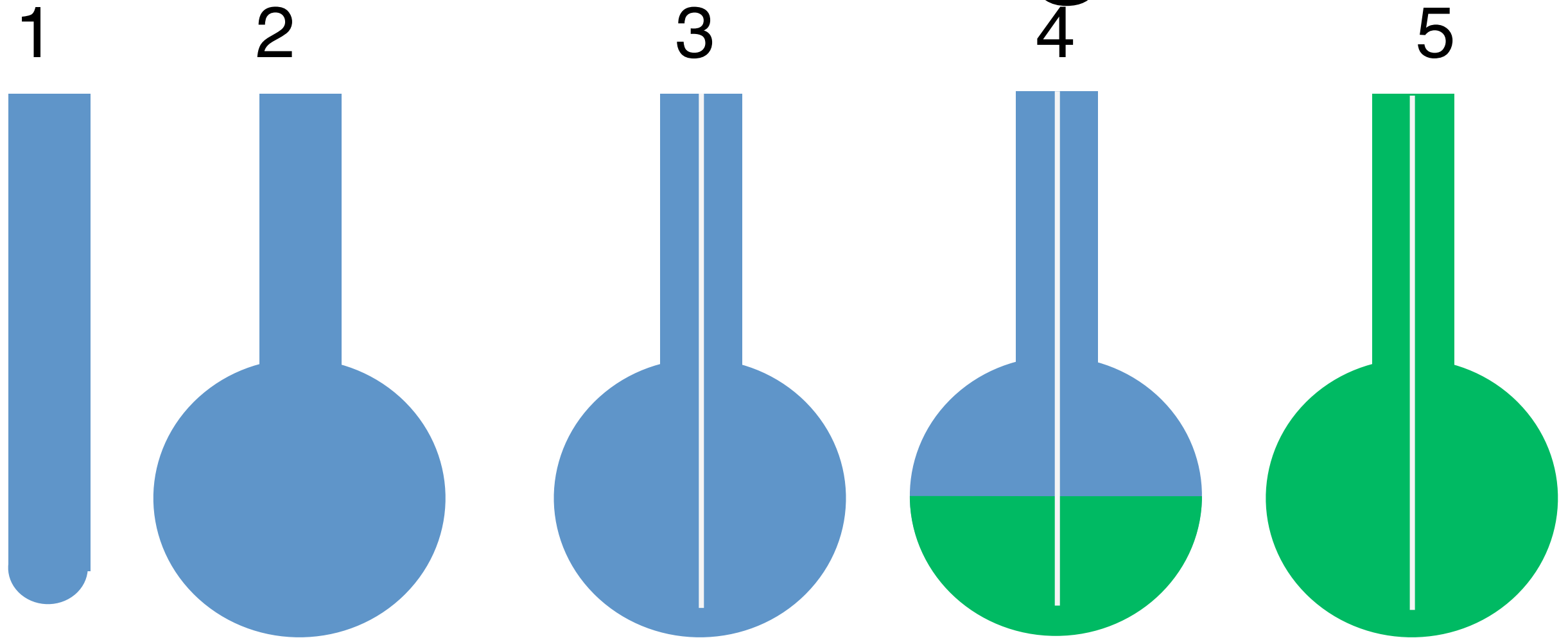
Purification of KamLAND-Zen LS

KamLAND	KamLAND-Zen
PC: 20%	PC:18%
Dodecane: 80%	Decane:82%
PPO: 1.36g/litter	PPO:2.7g/litter
	Xe gas: 2.44 wt%
density: 0.777 g/cm ³	density: 0.777 g/cm ³



- KamLAND-Zen LS was separately distilled and mixed.
- New PC and Decane were purified by both water extraction and distillation methods.
- Remain PPO at KamLAND distillation campaign was used with distillation.
- LS was purged by ultra pure N₂ gas before dissolving Xe gas.
- Preparing 2 set of LS, one w/o Xe for balloon enlarging and the other for Xe dissolving.

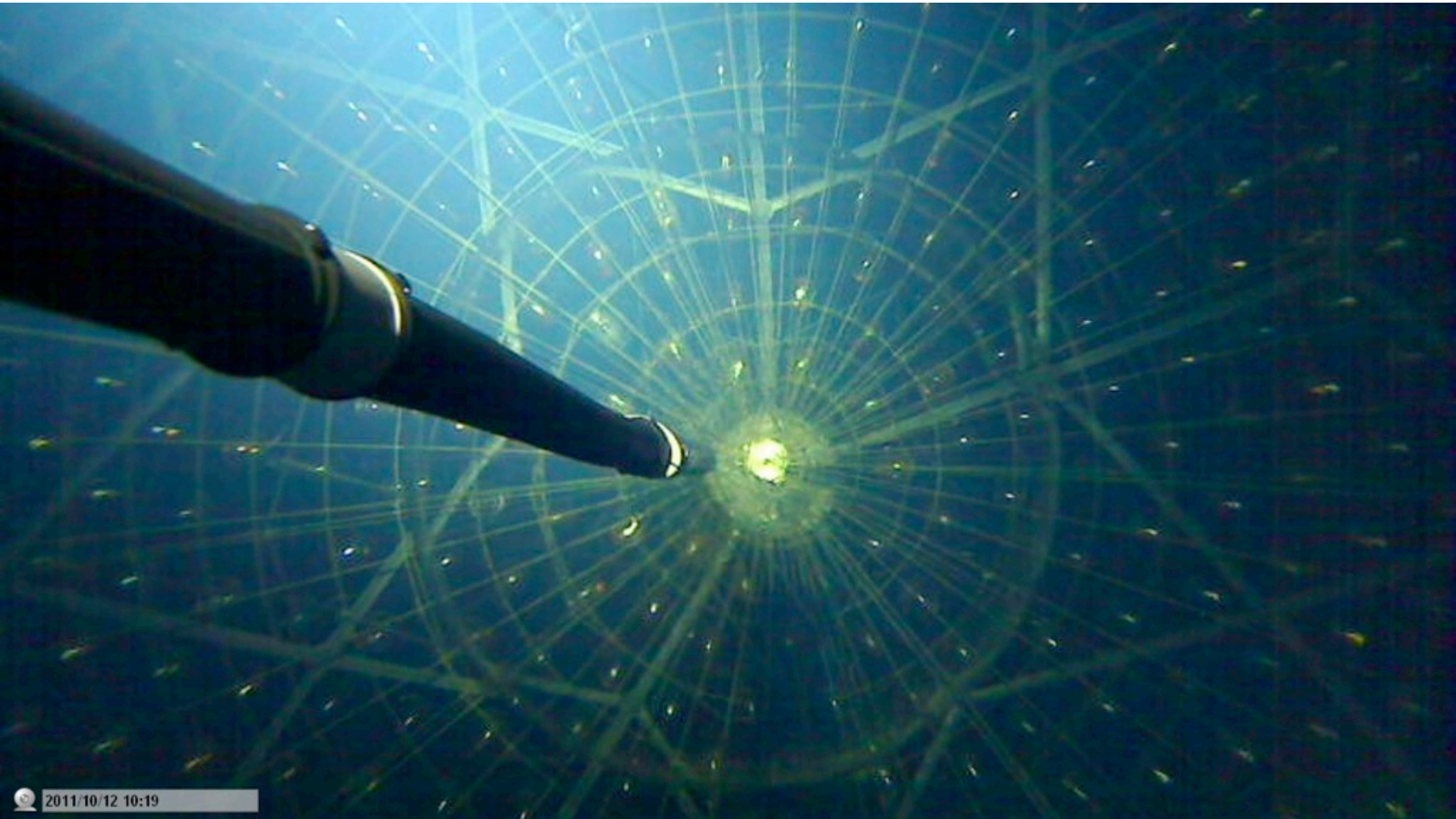
XeLS filling



1. 8/17 Mini balloon installation
2. 8/23-27 Dummy LS filling
3. 8/27-31 Agitation
4. 9/10-17 Xe-LS filling
5. 9/17-21 Agitation

Control LS density, weight of inner balloon and temperature precisely to keep LS boundary

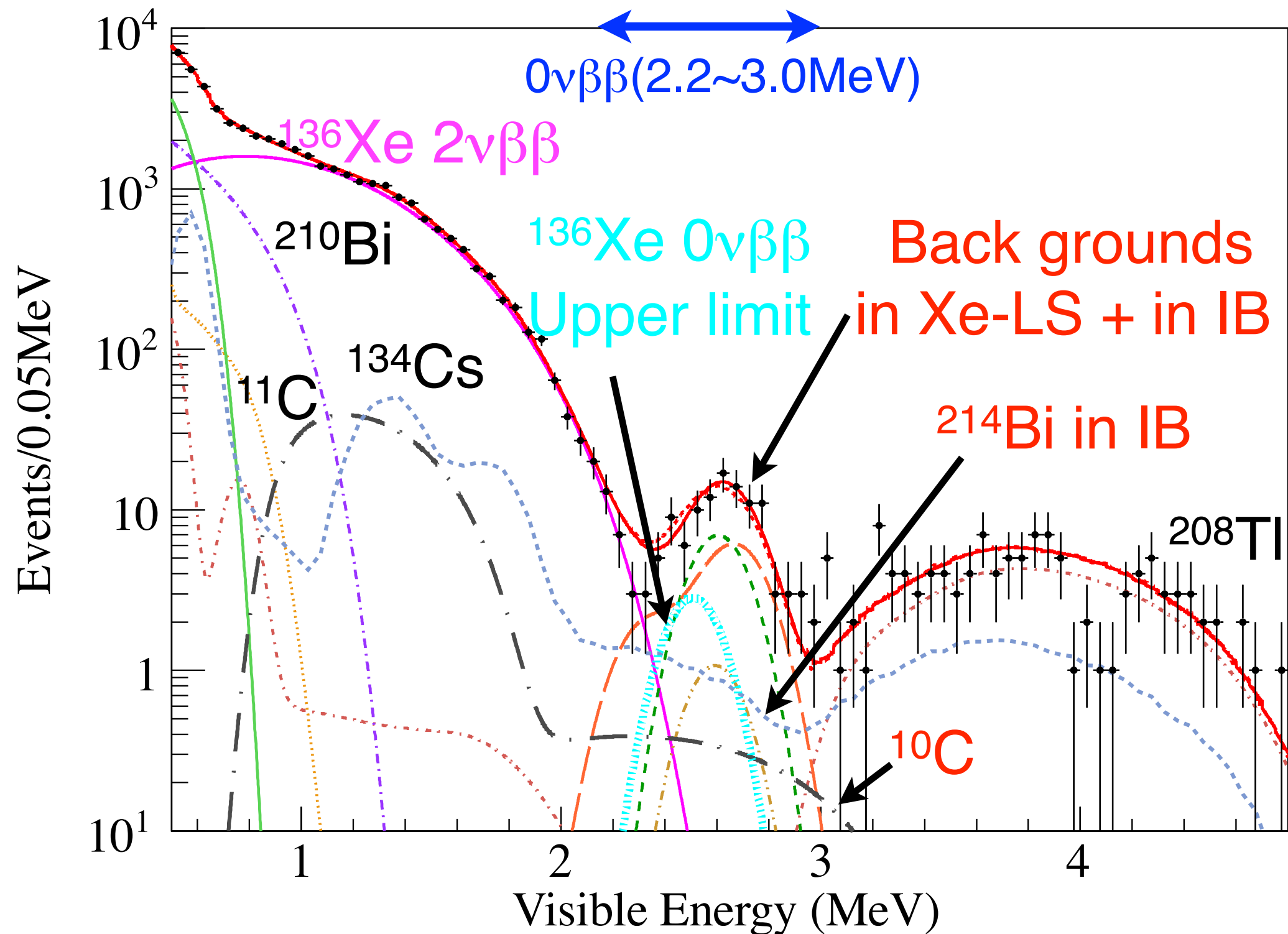
Inner Balloon



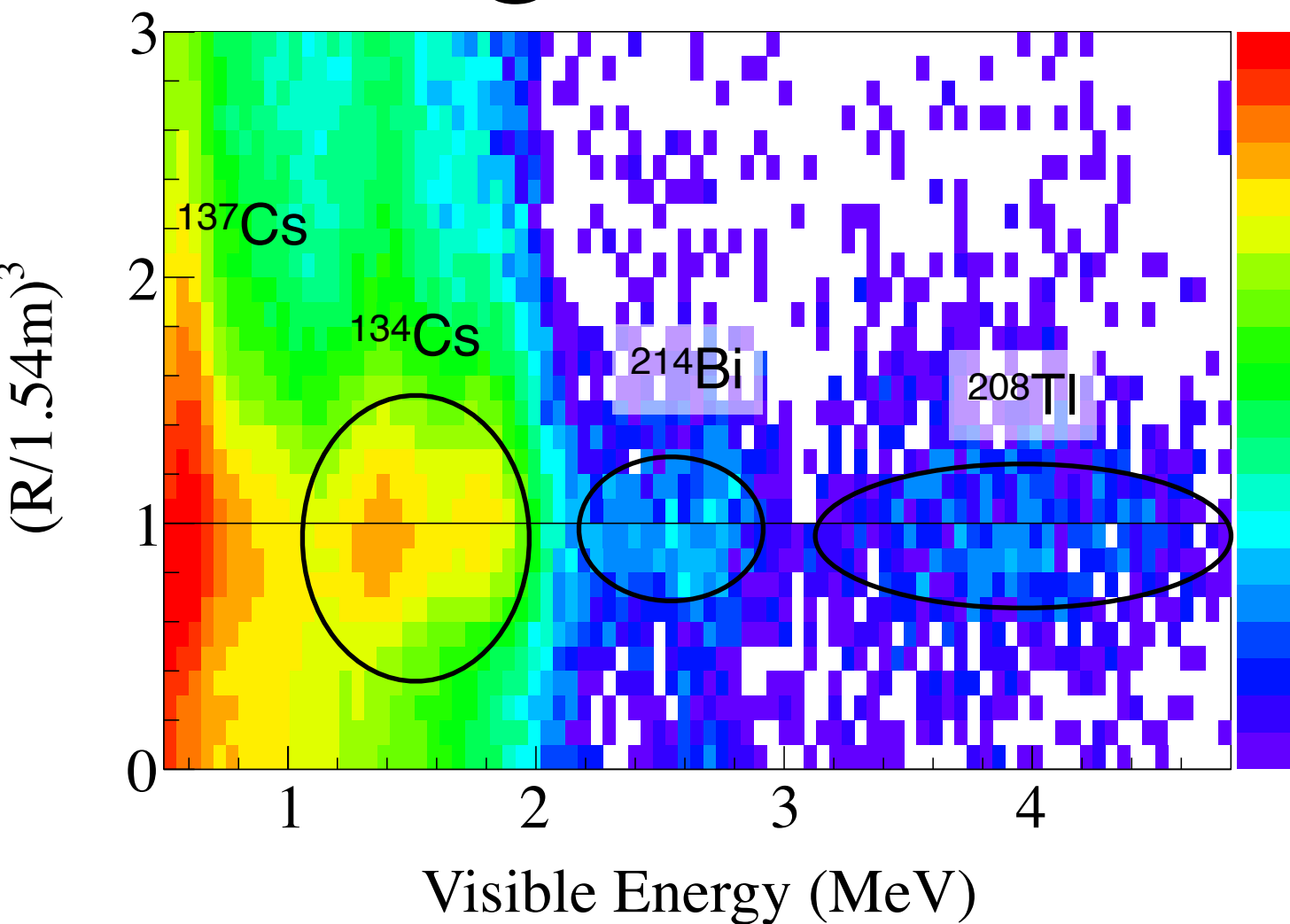
1st Result

Physical Review C 85,045504(2012)

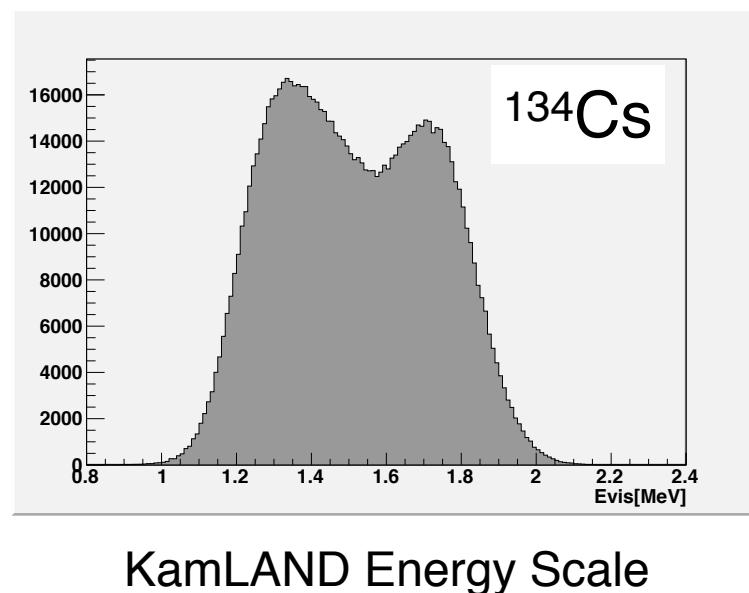
Live time 77.6 days



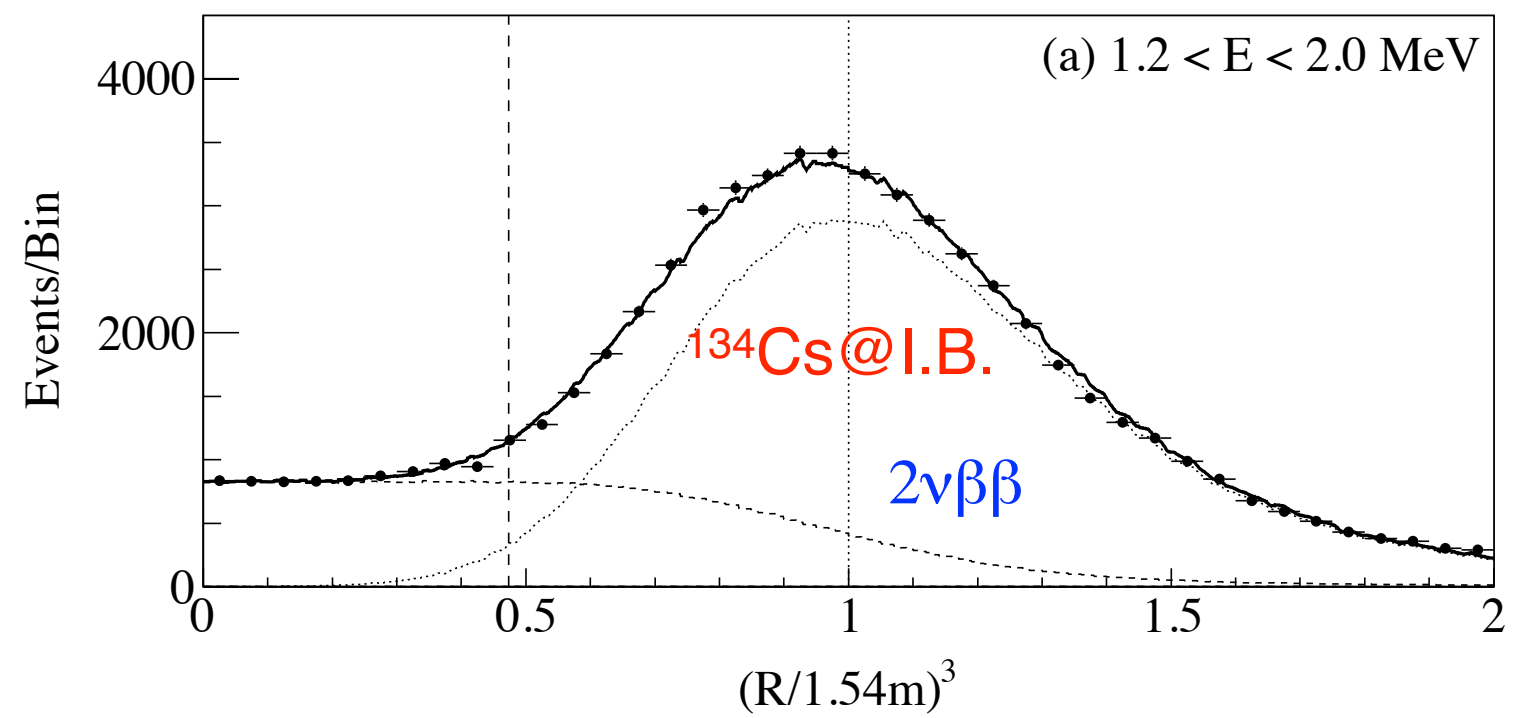
Backgrounds on Inner Balloon



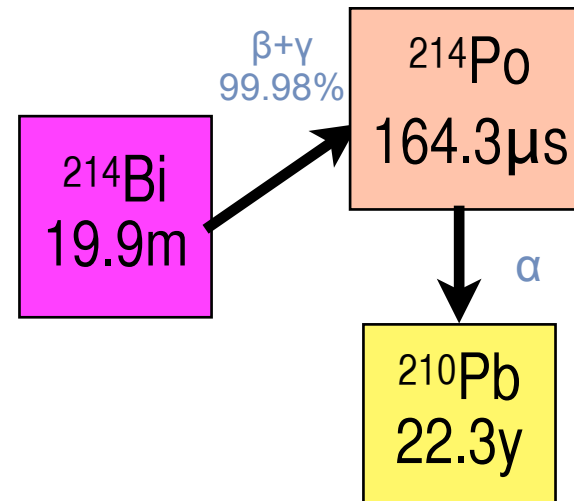
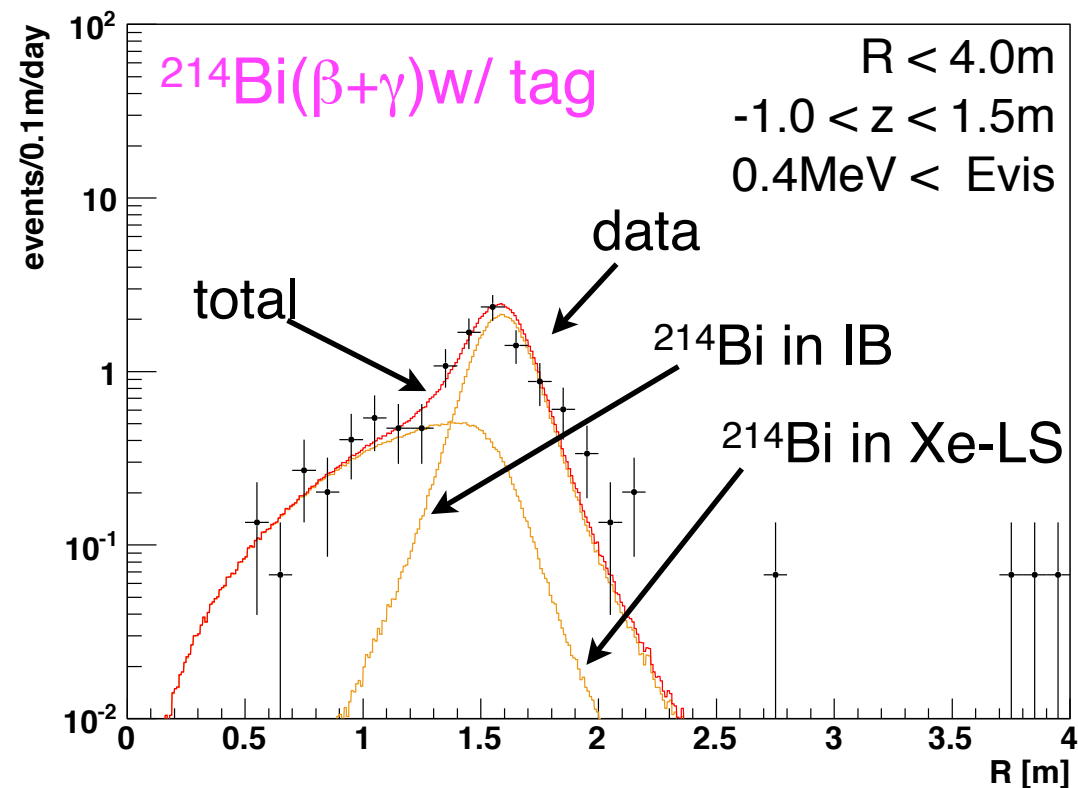
- ◆ $^{134}\text{Cs}/^{137}\text{Cs}$ ratio ~ 0.8 is similar to Fukushima-1 disaster.
- ◆ ^{136}Xe spallation can make Cs but ^{137}Cs is hard to generate.
- ◆ We made inner balloon in Sendai.
- ◆ In RCNS, $^{134}\text{Cs}/^{137}\text{Cs}$ ratio is $0.82 \sim 0.86$ @ Jan.2012 .



R^3 distribution



U and Th in LS and IB



U and Th in LS [g/g]

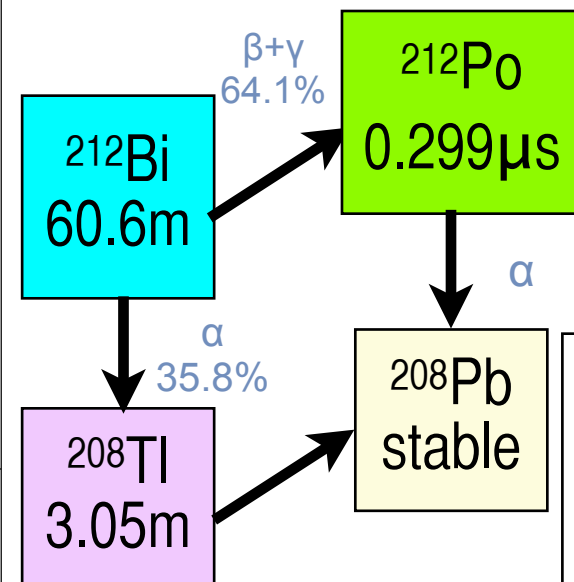
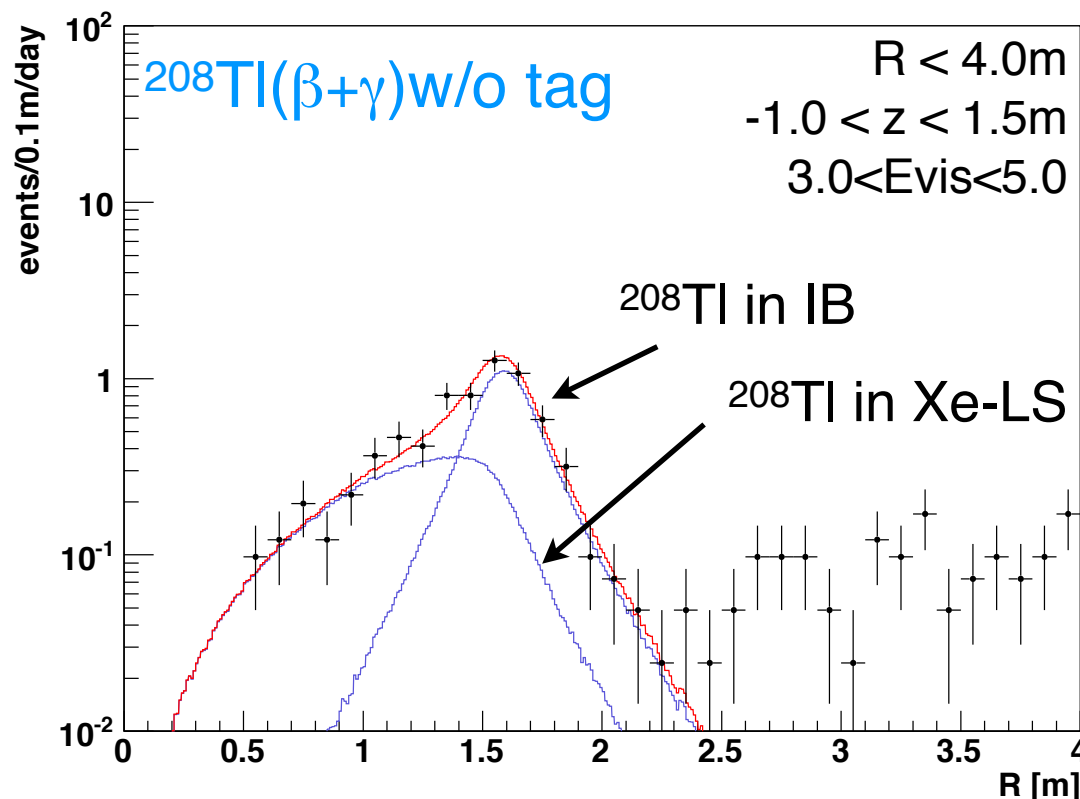
	Xe-LS	KamLAND
^{238}U	1.3×10^{-16}	3.5×10^{-18}
^{232}Th	1.8×10^{-15}	5.2×10^{-17}

XeLS has **2 order higher** impurities than KamLAND.

U and Th in IB[g/g]

	IB	film
^{238}U	$\sim 10^{-11}$	1.9×10^{-12}
^{232}Th	$\sim 10^{-11}$	4.9×10^{-12}

IB has **1 order higher** impurities than film.

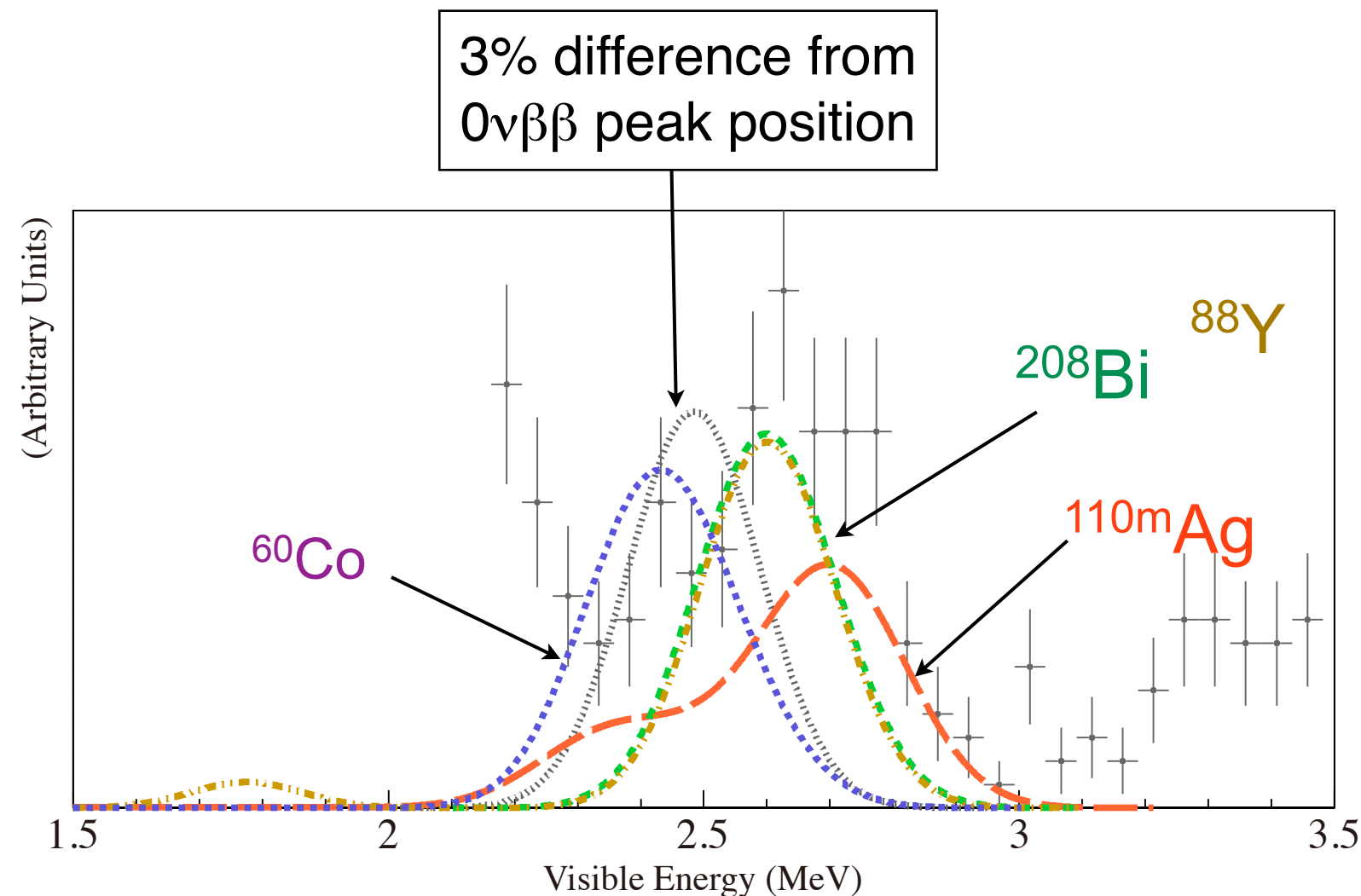


LS stayed in distillation area a few hours at KamLAND purification, but Xe-LS kept in tank a few weeks. New longer path to dissolving Xe gas and filling inner-balloon.

B.G. around $0\nu\beta\beta$ Energy

How to find

- Follow every ENSDF cascade info.
- Make KamLAND energy spectrum of $\beta^- (+\gamma)$, $\beta^+ (+\gamma)$ and EC(+ γ) decays accounting for the time structure of the chain and pile-up in DAQ.
- Search 2.4-2.8 MeV peak by eye.
- Search long lived parent > 30days for each candidates.
- 4 candidates remain.

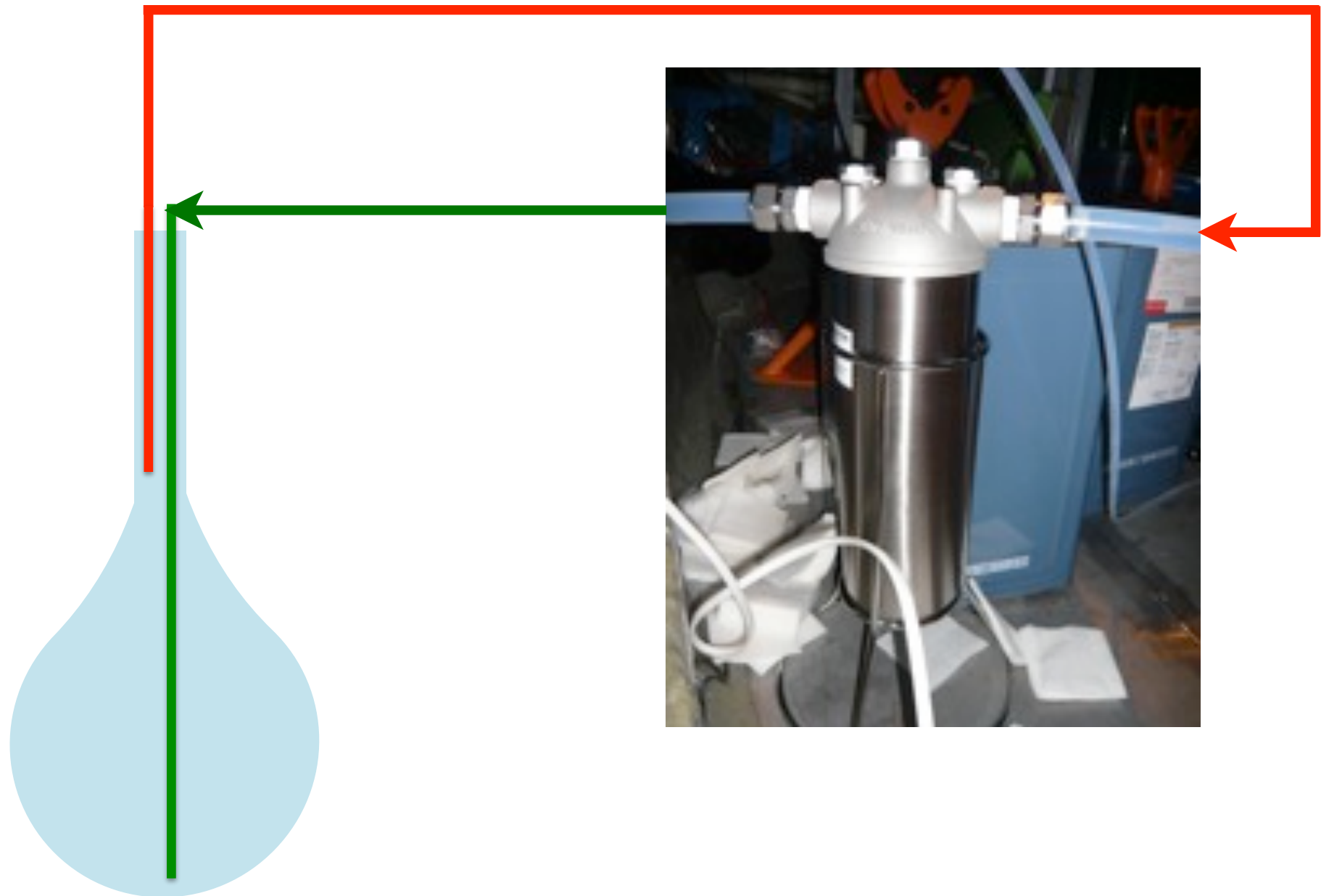


	decay	life(τ)	χ^2_{spectrum}
^{88}Y	EC + γ	154 day	22.2
$^{110\text{m}}\text{Ag}$	$\beta^- + \gamma$	360 day	13.1
^{208}Bi	EC + γ	5.31×10^5 year	22.7
^{60}Co	$\beta^- + \gamma$	7.61 year	82.9

Difficult to explain these isotopes are generating by cosmic-ray muon in KamLAND area.
 But spallation during **Xe gas transfer** from enriched plant to Kamioka can explain ^{88}Y and $^{110\text{m}}\text{Ag}$ productions.

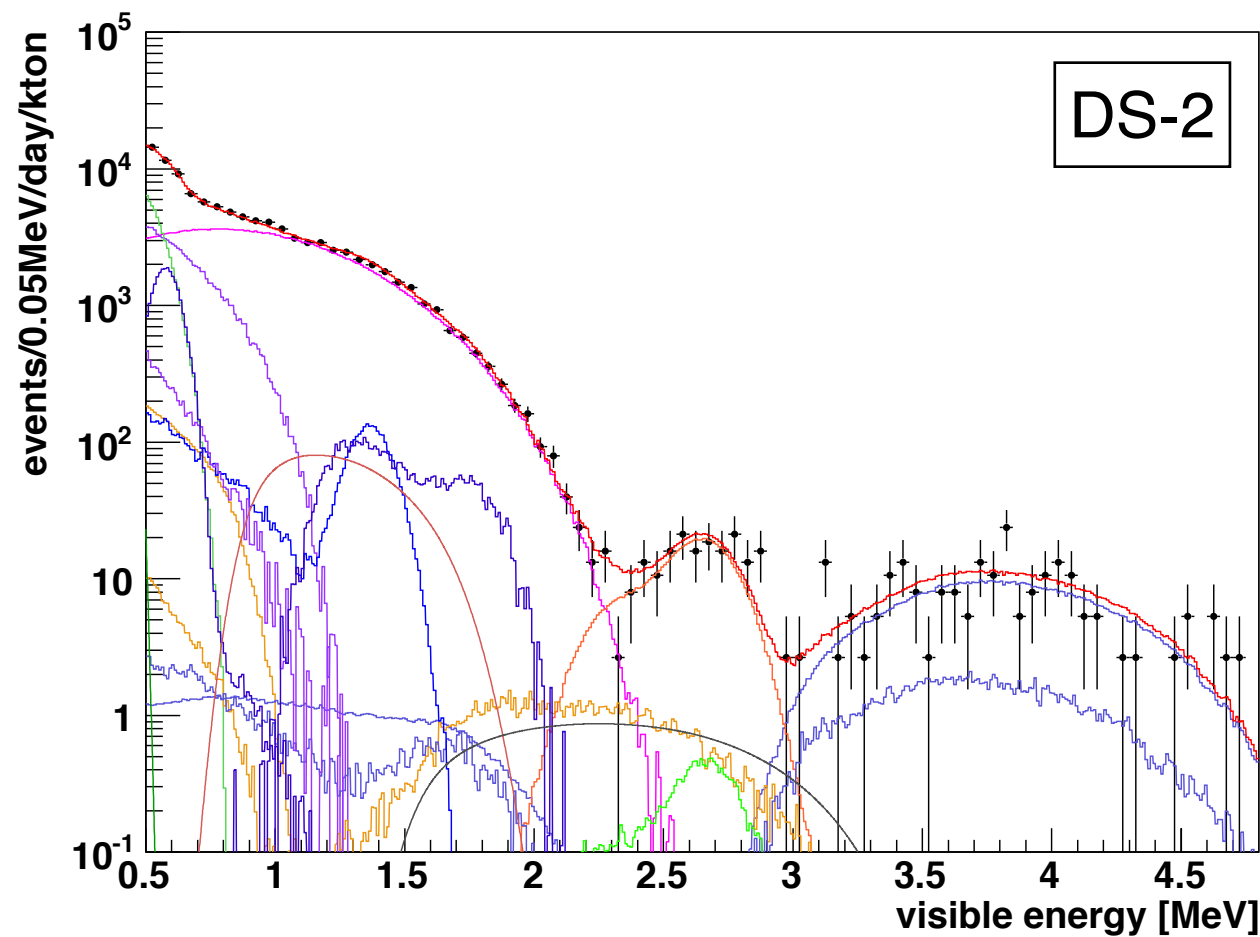
Filtration

- Purification using 15nm filter in Feb. 2012.
- 2.3 volume of Xe-LS was filtrated.
- Teflon tube was installed inside IB and keep it.

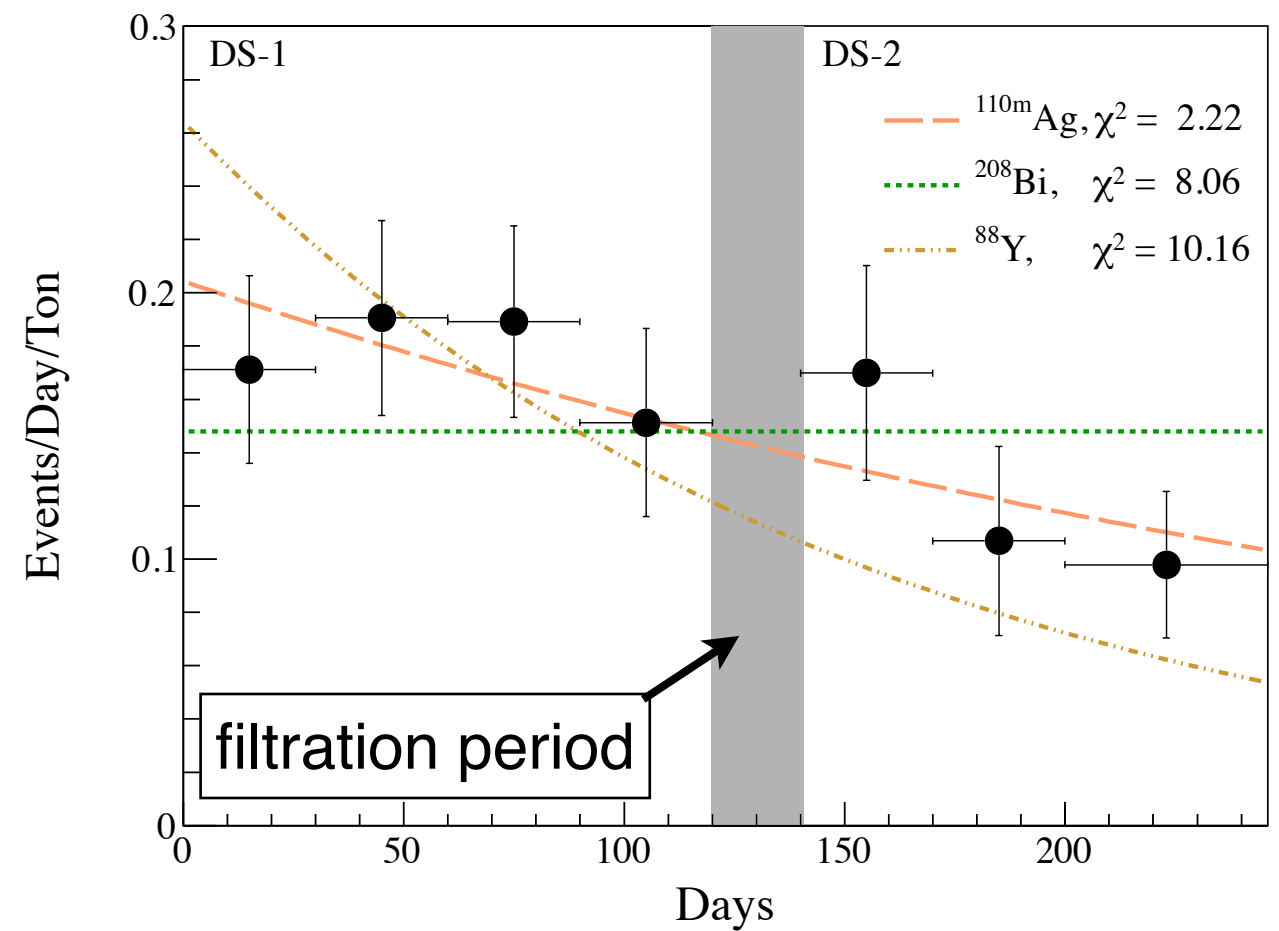


After Filtration

Energy Spectrum After Filtration

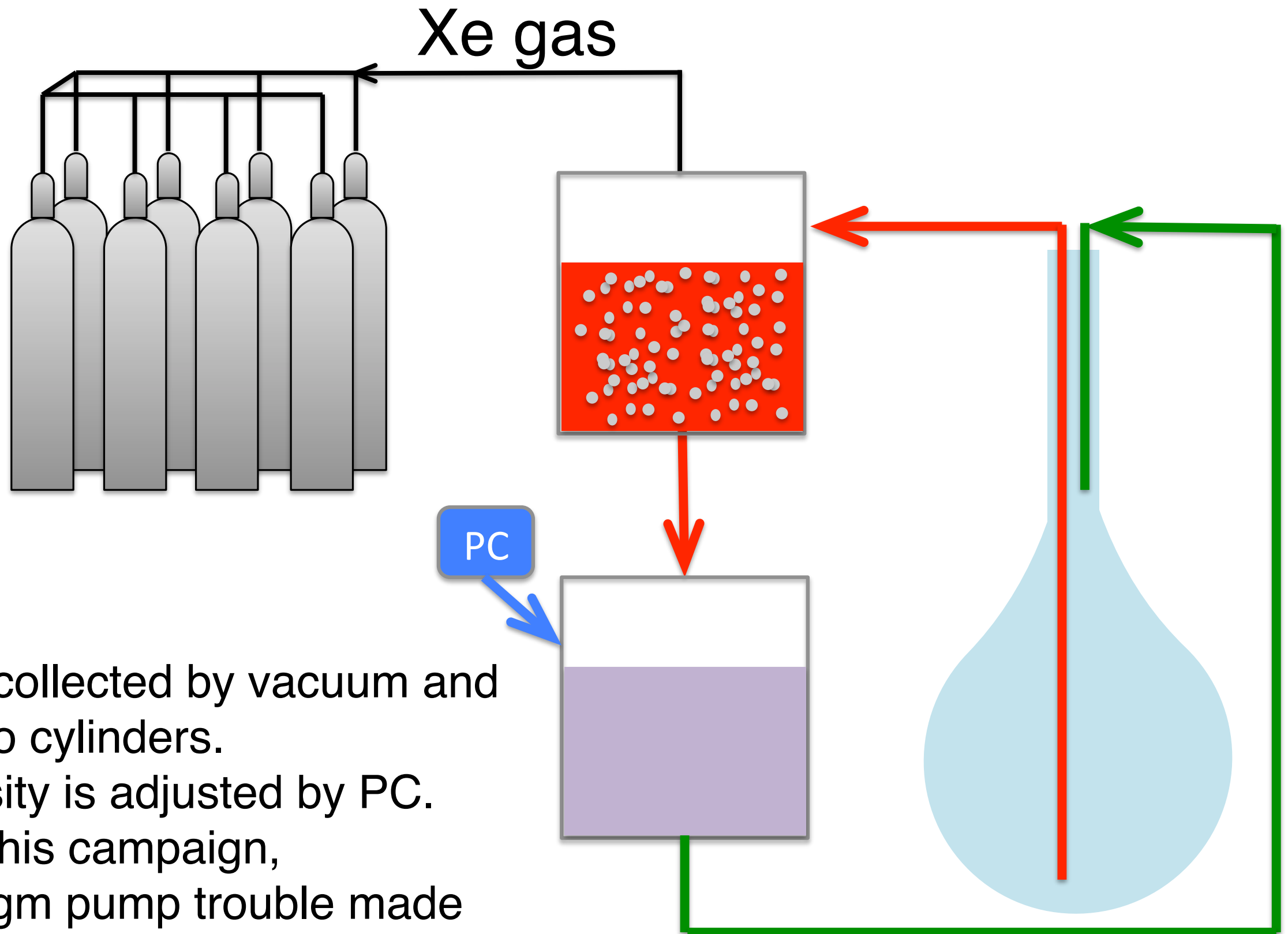


Time Variation @2.2~3.0 MeV



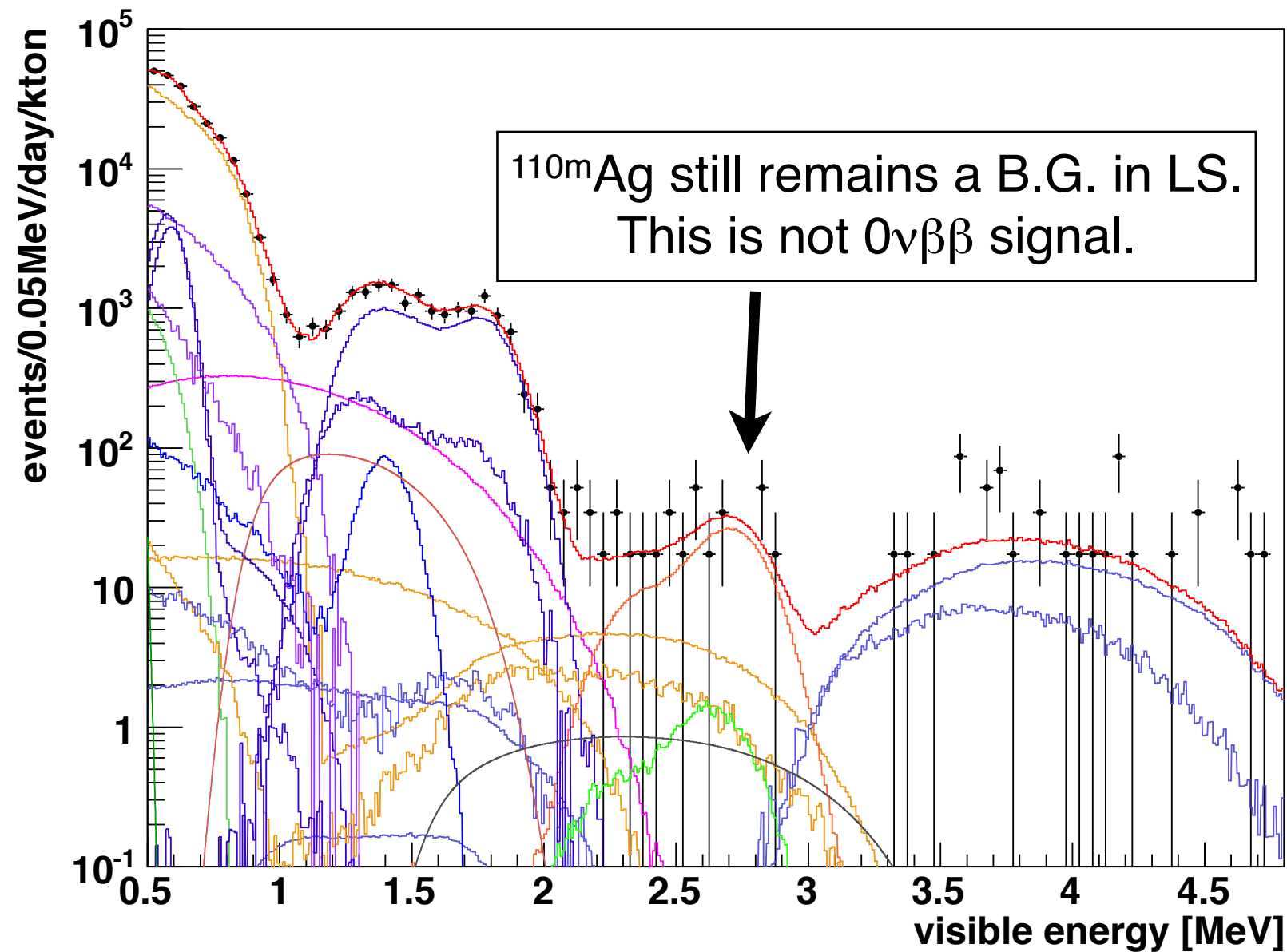
No difference about energy spectrum around 2.2 ~ 3.0 MeV region.
From time variation of event rate, ^{110m}Ag isotope is favored as background candidate.

Xe Collection



- Xe gas collected by vacuum and filled into cylinders.
- LS density is adjusted by PC.
- During this campaign, diaphragm pump trouble made Cs increasing.

After Xe Collection



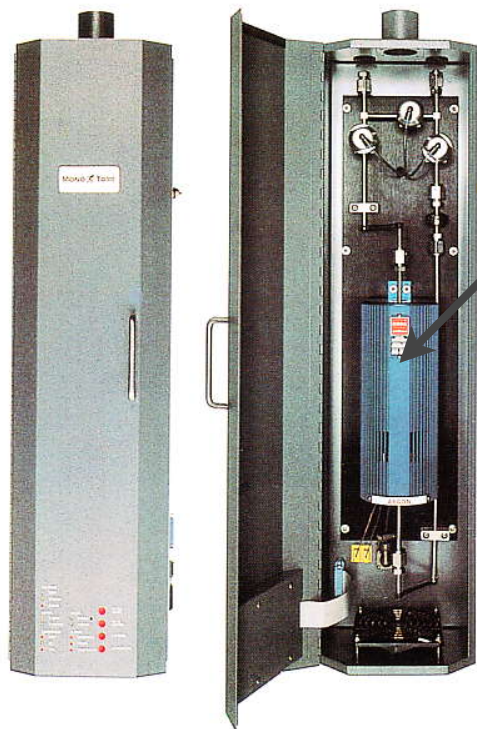
Decide to do LS and Xe purification !!

Xe Purification

Borrow from XMASS group
used to remove Kr

K.Abe et. al, Astropart. Phys. 31,290-296(2009)

- Remove impurities in Xe gas by distillation
- Additional purification using getter.



Zr alloy

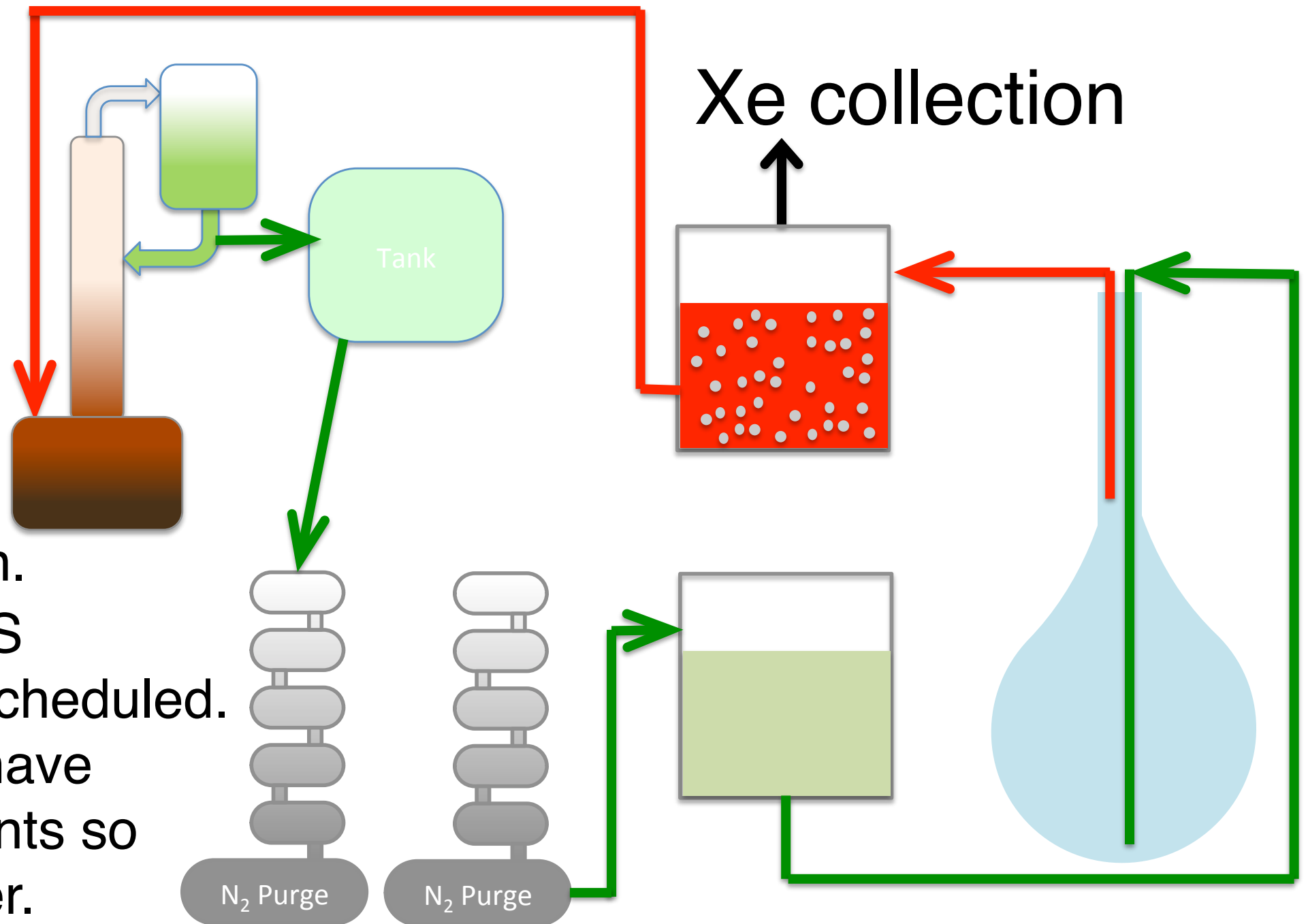
Catch $\text{H}_2\text{O}, \text{N}_2, \text{O}_2,$
 $\text{CH}_4, \text{CO}, \text{CO}_2$
 < 1 [ppb]
Also catch metals



Distillation Tower

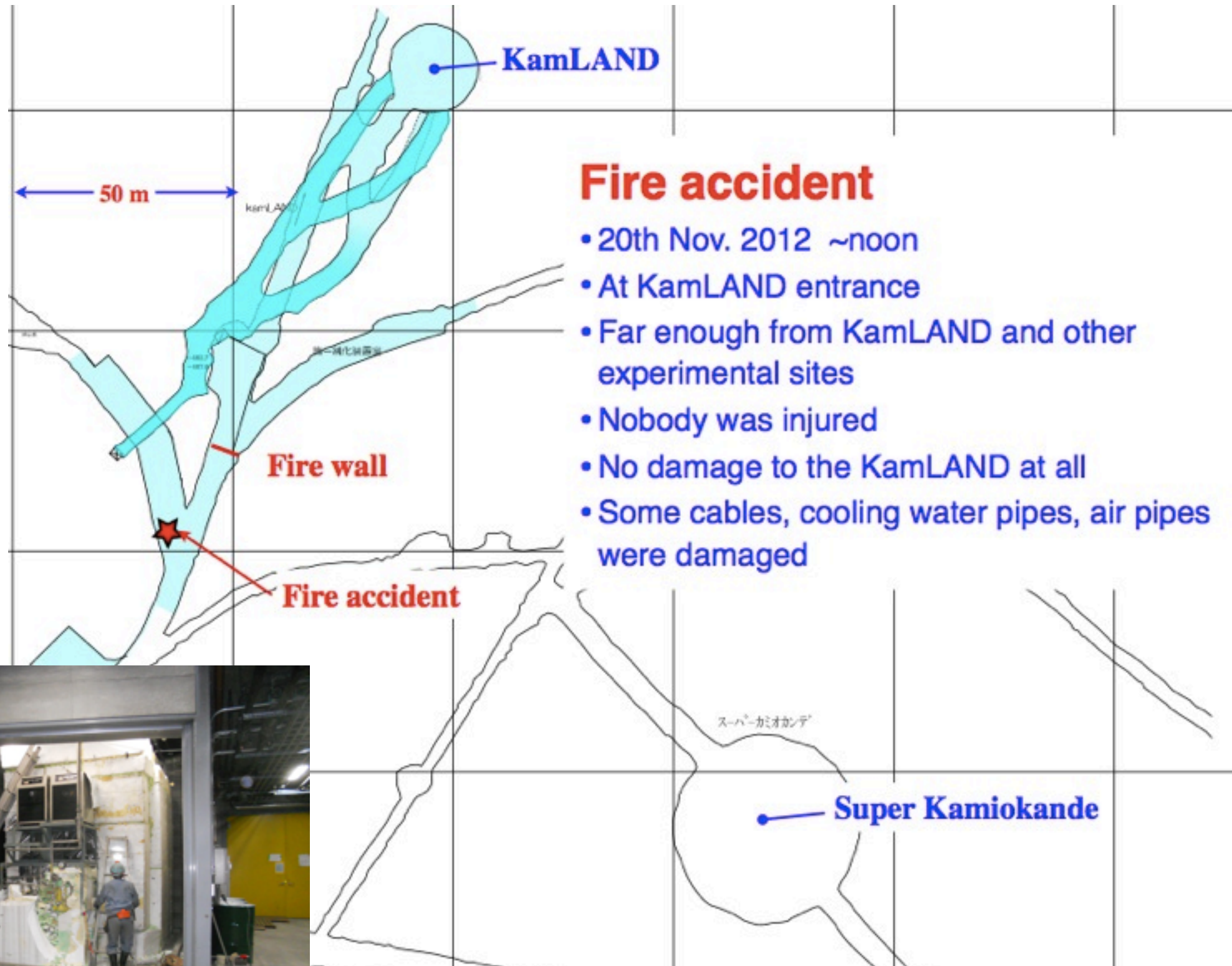
LS Purification

- 1/10 $^{110\text{m}}\text{Ag}$ rate expectation for 1 volume circulation.
- 3 volume of Xe-LS purification was scheduled.
- PC and Decane have similar boiling points so distilled by 1 tower.
- PPO remains distillation tower and distilled @ final cycle.
(1st and 2nd cycle LS w/o PPO return to IB and
3rd cycle LS w/ PPO return to IB)



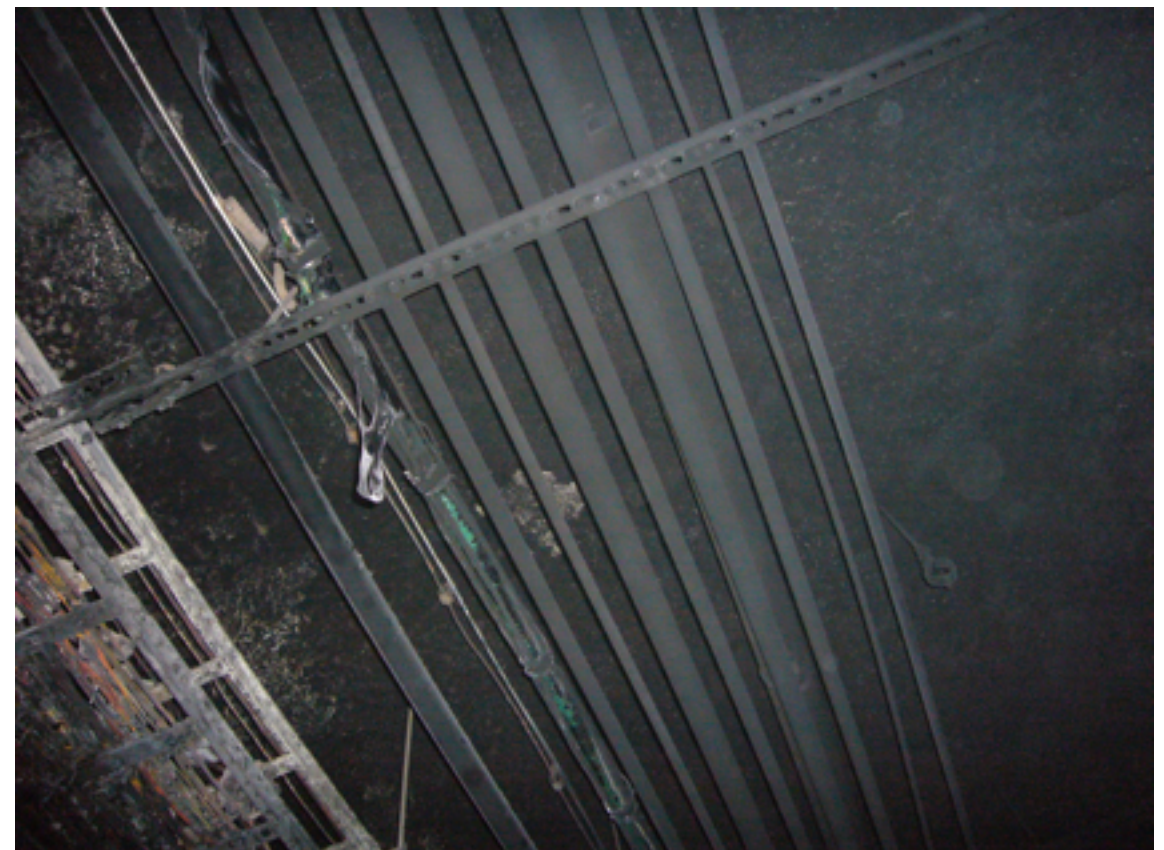
@ 1st cycle over...

Fire @ 2012/11/20



Destructing Rn-less Air Generator

Fire @ 2012/11/20



Current

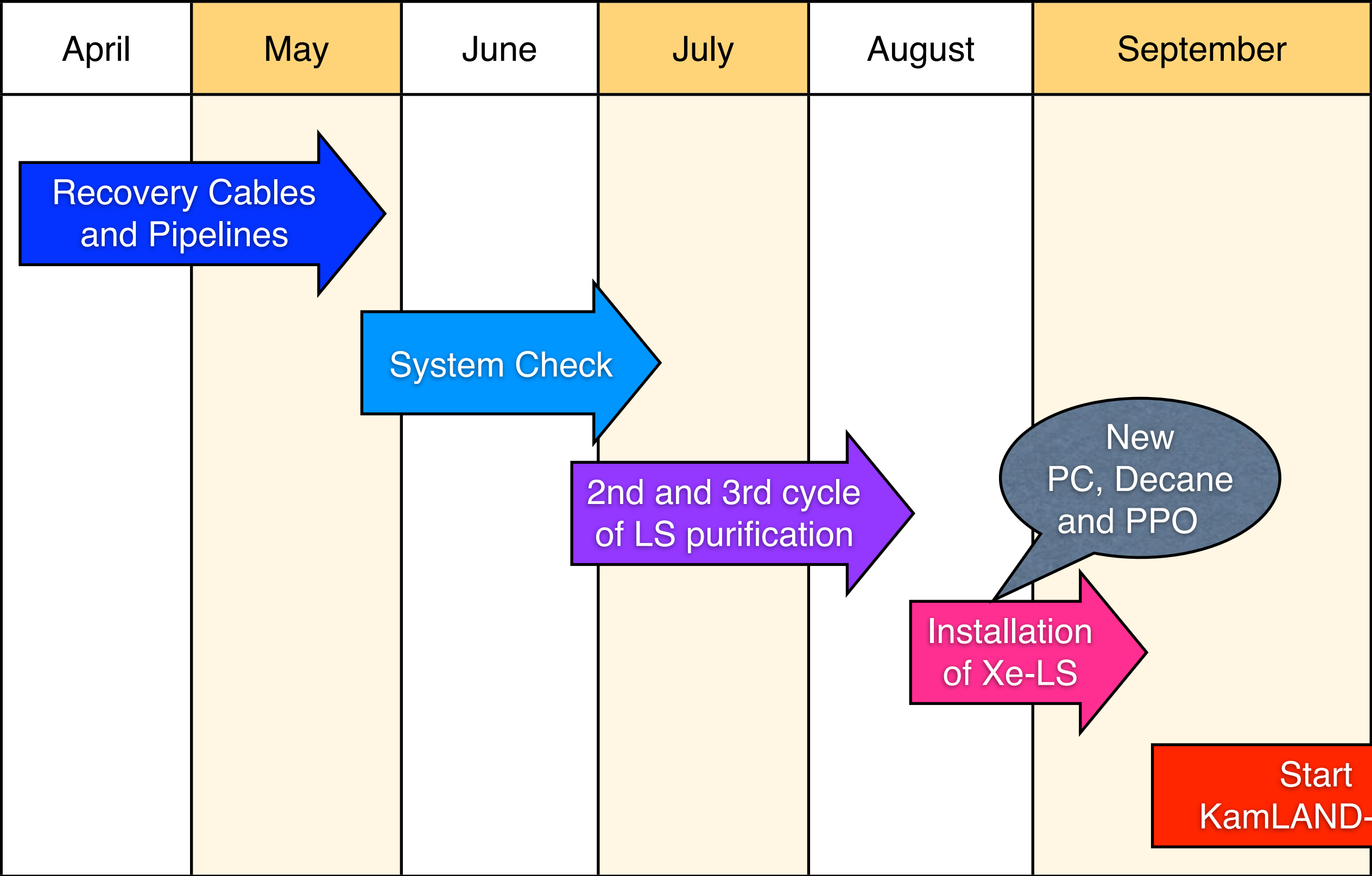


No damage for KamLAND detector, KamLAND-Zen balloon and DAQ system.

Quick recovering main power line, network, and alarms, re-start normal DAQ from **December 17th**.

Now recovering damaged cables and pipelines.

Schedule



Summary

- KamLAND-Zen reports 2 results of double beta decay measurements [PRC 85(045504), PRL 110(062502)] and 1 result of Majoron emitting [PRC 86(021601)].
- Purification of unexpected BG $^{110\text{m}}\text{Ag}$ is going on.
- We will start ^{136}Xe double beta decay measurement in September.
- Study for next phase ($\sim 700\text{kg } ^{136}\text{Xe}$) started.
Clean inner balloon construction, LS and Xe purification.