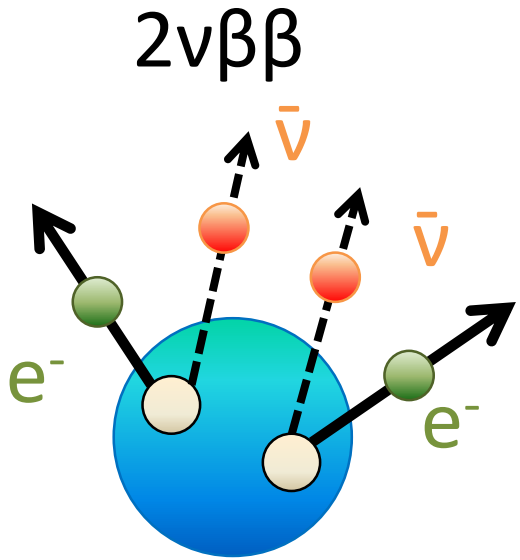
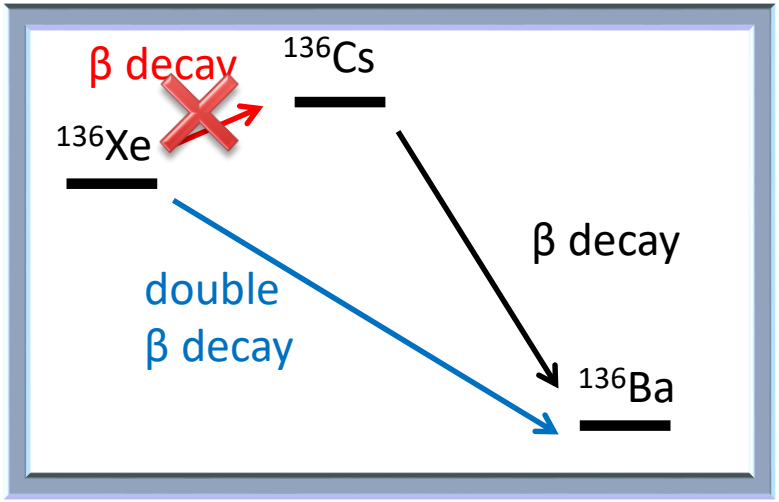
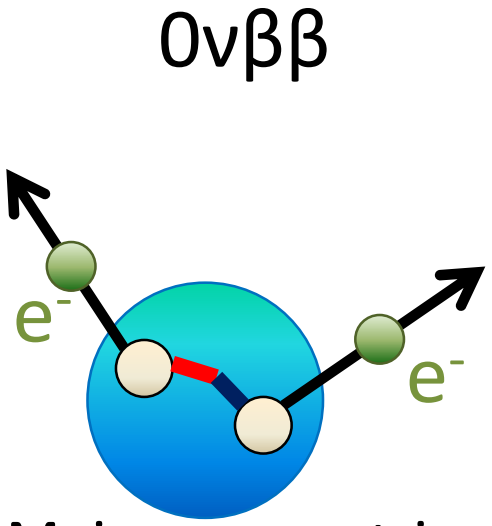
KamLAND-Zen

DBD2018 in Hawaii
2018/10/21
Research Center for Neutrino Science
Tohoku University
H. Ikeda

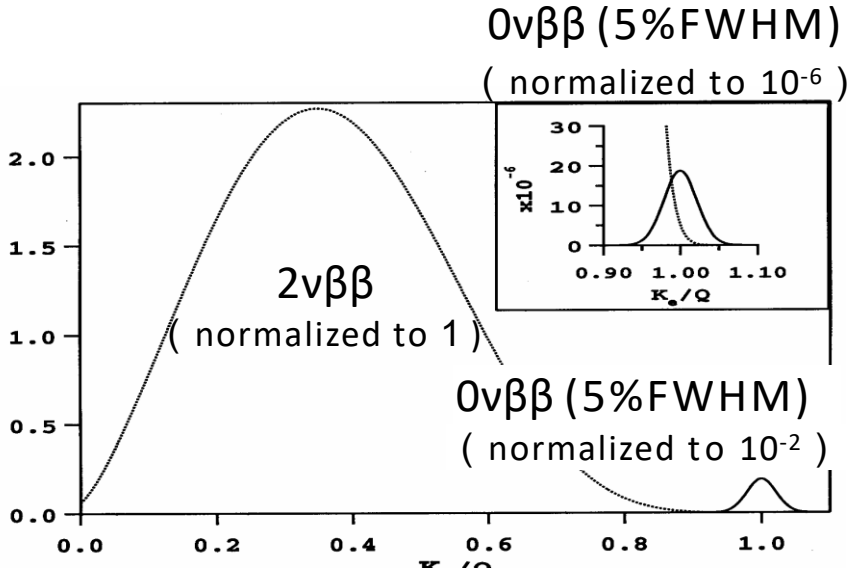
Neutrinoless double β decay







Majorana neutrino



$$\langle m_{\beta\beta} \rangle = \left| \Sigma_i U_{ei}^2 m_{\nu_i} \right|$$

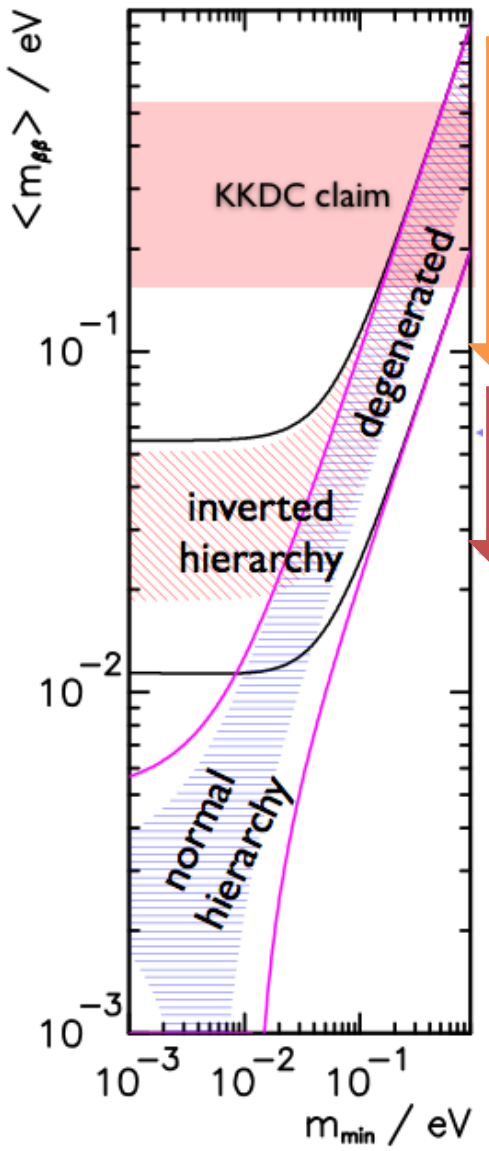
$$[T_{1/2}^{0\nu}]^{-1} = G^{0\nu} |M^{0\nu}|^2 \langle m_{\beta\beta} \rangle^2$$

Majorana neutrino …

- ✓ Lepton number violation
- ✓ Light neutrino mass
- ✓ Leptogenesis

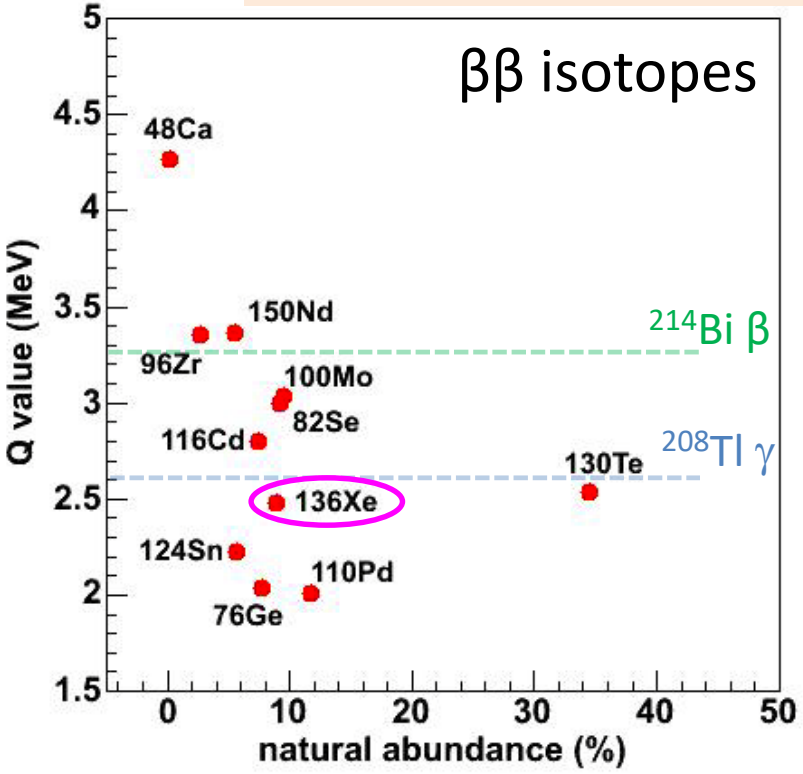
0νββ Targets

High Q value : BG free
High N. A. : No enrichment



~60meV
10^2~10^3 kg targets
$T_{1/2}$: 10^{26} ~ 10^{27} y

~20meV
10^3~10^4 kg targets
$T_{1/2}$: 10^{27} ~ 10^{28} y



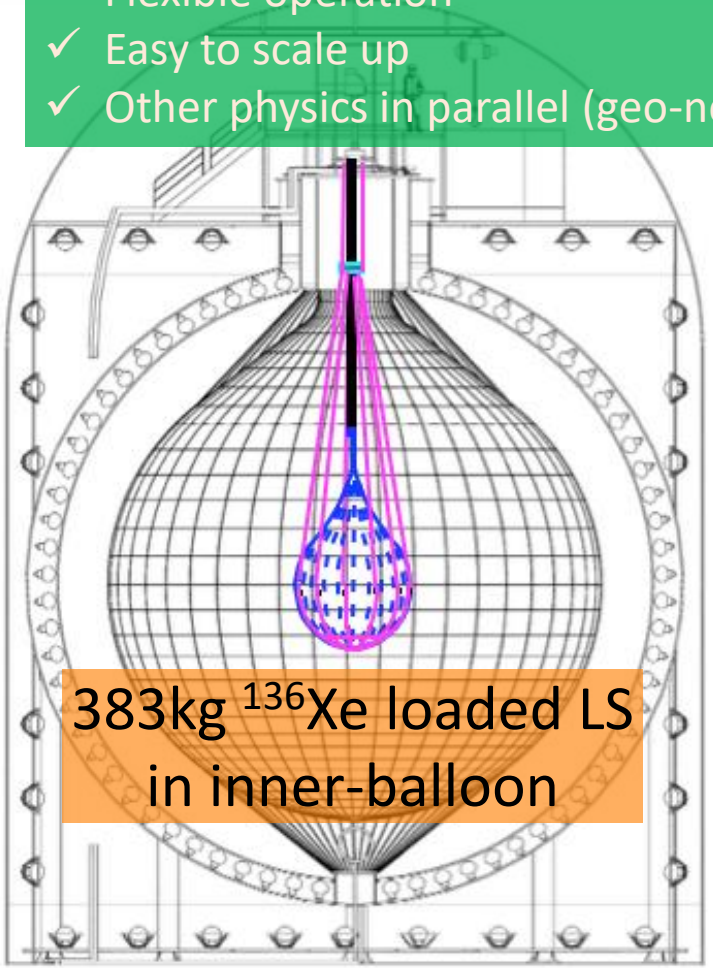
- **Large number of 0νββ targets.**
- **Background free detector.**
- **High vertex/energy resolution.**

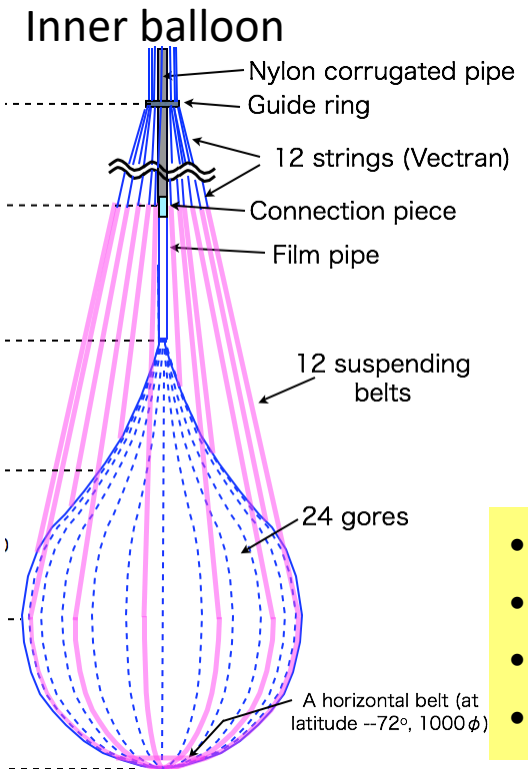
KamLAND-Zen 400

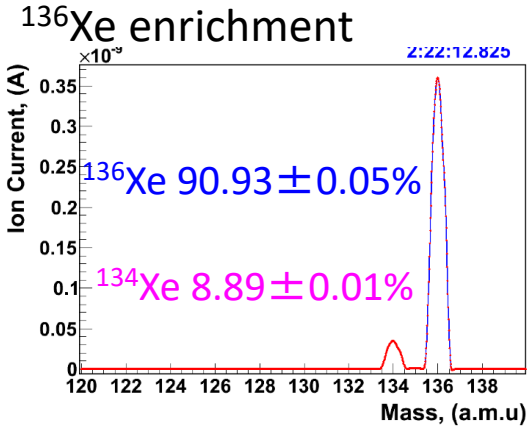
Kamioka Liquid-scintillator Anti-Neutrino Detector Zero neutrino double beta decay search

KamLAND
- ✓ Quick start with relatively low cost
- ✓ Flexible operation
- ✓ Easy to scale up
- ✓ Other physics in parallel (geo-neutrino, SN, …)

^{136}Xe
- ✓ Noble gas
- ✓ Enrichment (91% ^{136}Xe)
- ✓ Dissolving into LS (> 3 wt%)
- ✓ Long lived 2νββ







- Nylon film: 25μ-thick
- U,Th~10^{-12}, ^{40}K~10^{-11}g/g
- Xe tightness
- >95% transparent @400nm

KamLAND-Zen 400 Construction

2011 | 2012 | 2013 | 2014 | 2015

5 9

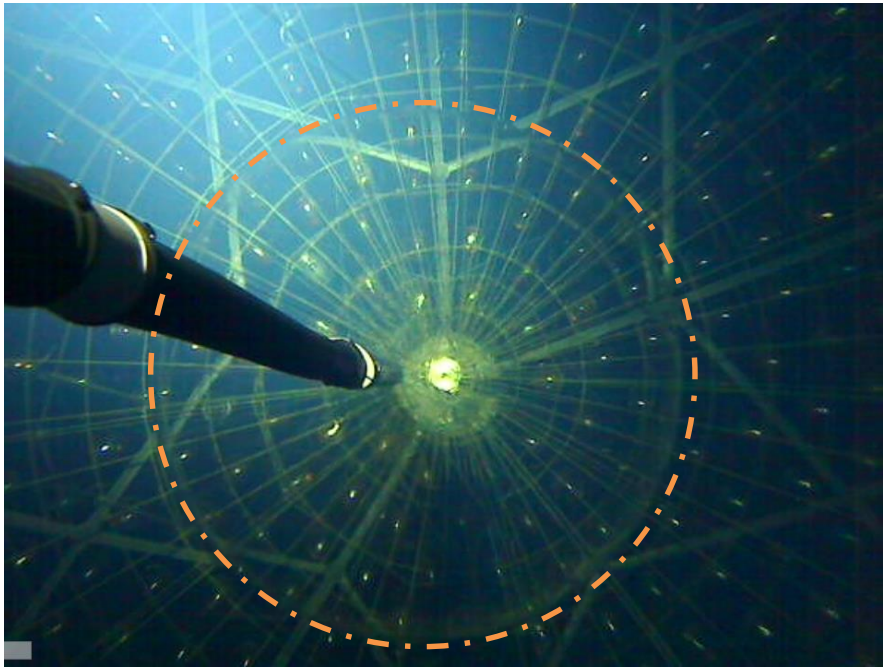
Construction

Installation

Xe dissolving system

Class 1 super clean room @ Junichi Nishizawa Memorial Center, Tohoku University

Xe loaded LS filling



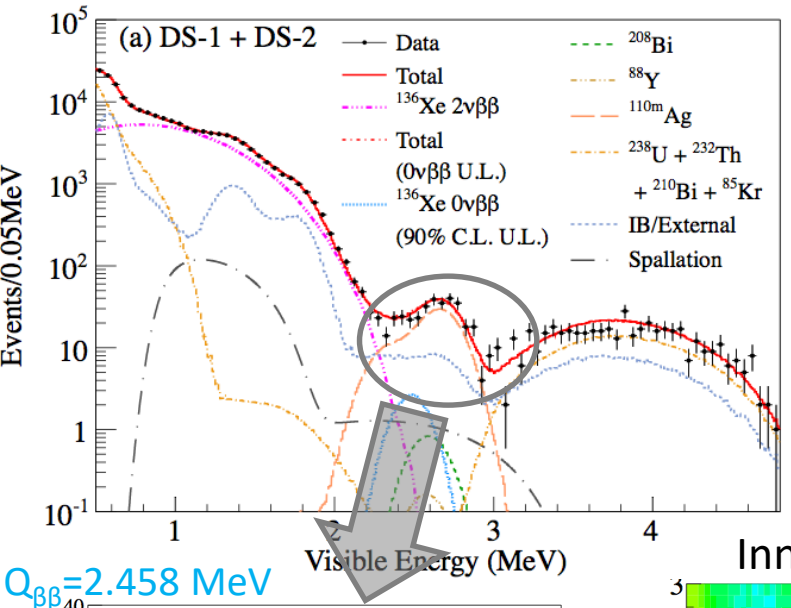
LS Decane(82%) + PC(18%) + PPO(2.7g/l)
LS purified by water extraction & distillation
320 kg enriched Xe in LS

KamLAND-Zen 400 phase 1

2011 | 2012 | 2013 | 2014 | 2015

10 6

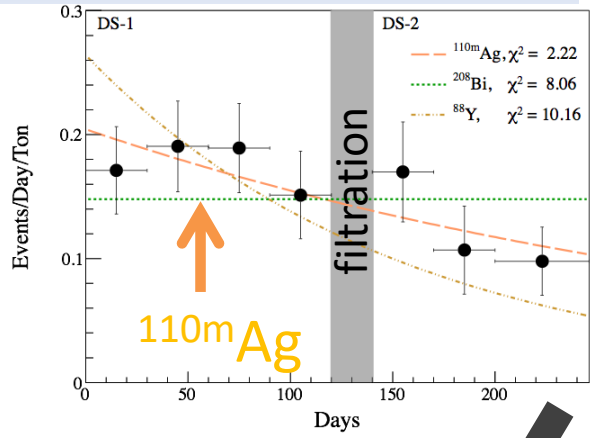
89.5kg-year ^{136}Xe measurement: $T^{0\nu}_{1/2} > 1.9 \times 10^{25}$ year (90%C.L.)



From ENSDF database candidates are ^{110m}Ag, ^{88}Y, ^{208}Bi, ^{60}Co

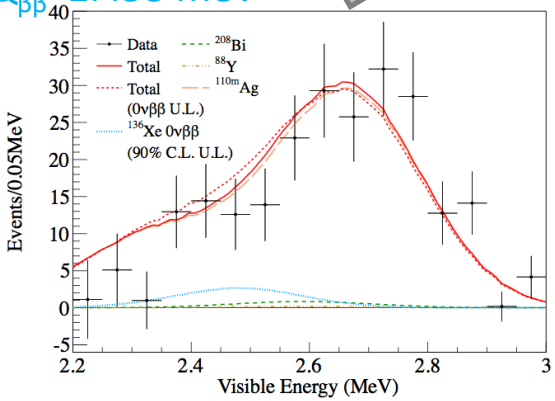
Where comes from?

- ^{136}Xe Spallation
- Fukishima-I reactor

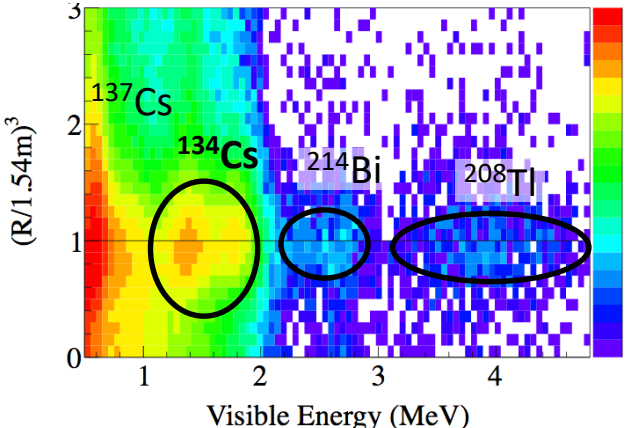


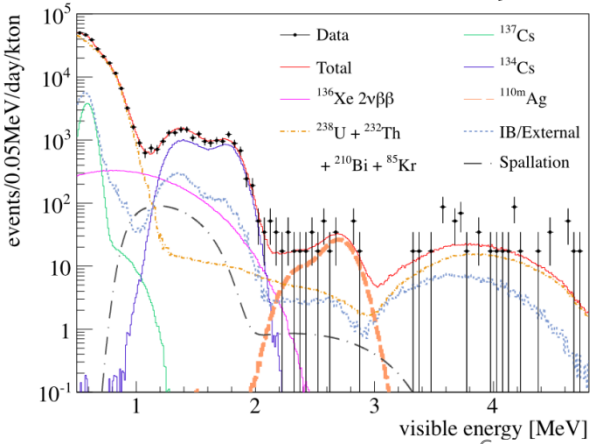
After Xe extraction

$Q_{\beta\beta}$=2.458 MeV



Inner balloon surface



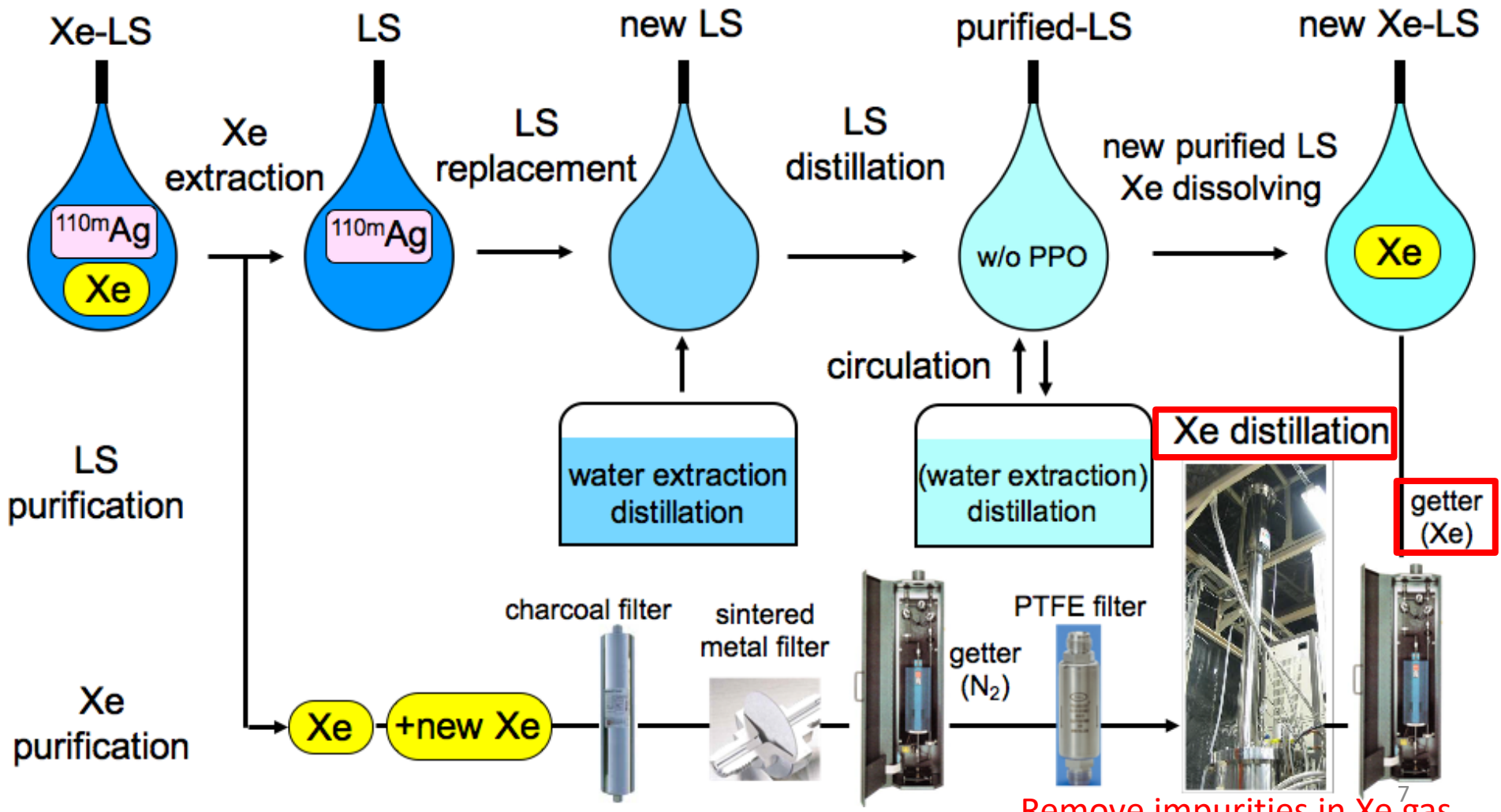


^{110m}Ag rate did not change

KamLAND-Zen 400 Purification

2011 | 2012 | 2013 | 2014 | 2015 | 2016

6 10



Remove impurities in Xe gas

KamLAND-Zen 400 phase 2

2011 | 2012 | 2013 | 2014 | 2015

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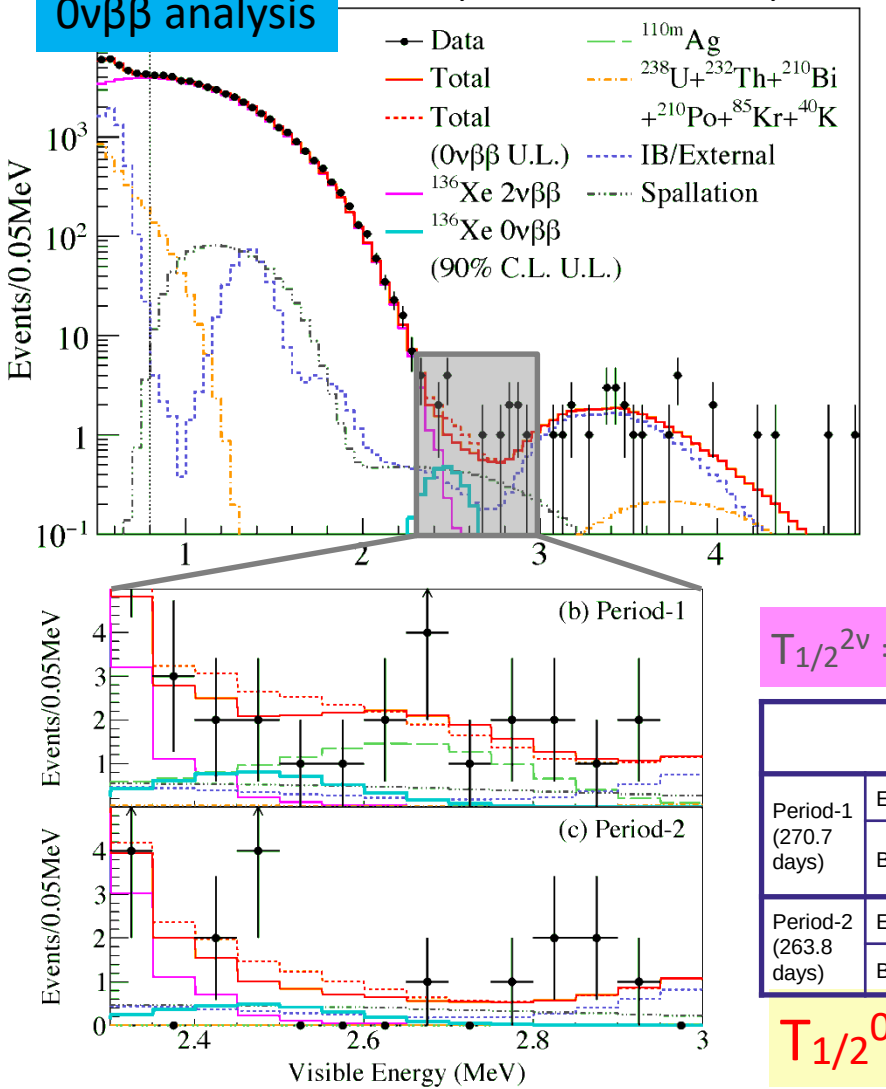
0νββ analysis

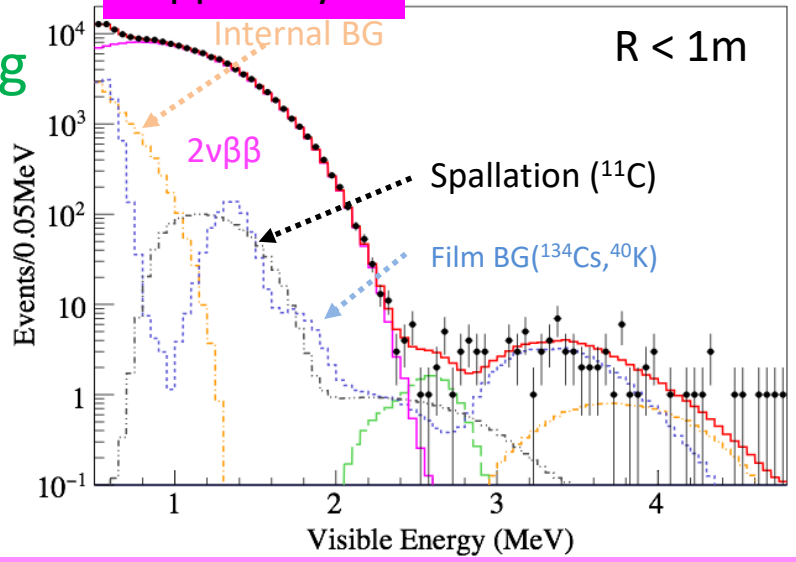
systematic uncertainty 3.1 %



Xe 383 kg

2νββ analysis

Small Film BG area

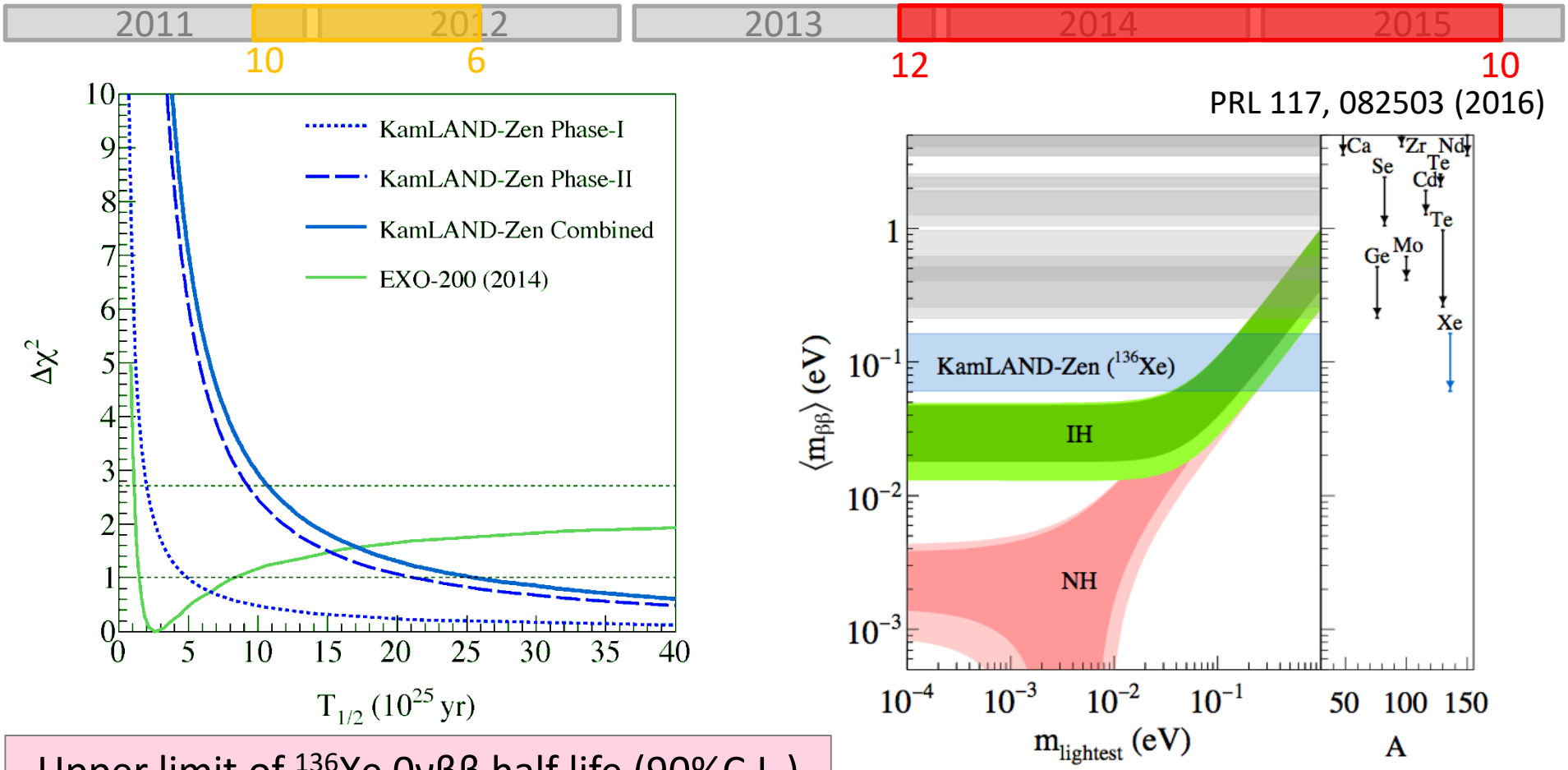


$T_{1/2}^{2\nu} = 2.21 \pm 0.02(\text{stat}) \pm 0.07(\text{syst}) \times 10^{21}$ year (90% C.L.)

		0νββ	2νββ	^{214}Bi LS	^{110m}Ag	^{214}Bi film	spallation	Total BG	Observed
Period-1 (270.7 days)	Estimated	-	-	0.23 ± 0.04	-	-	3.4 ± 0.8	-	22
	Best-fit	0	5.48	0.25	8.5	2.56	4.04	20.8	
Period-2 (263.8 days)	Estimated	-	-	0.03 ± 0.01	-	-	3.3 ± 0.8	-	11
	Best-fit	0	5.29	0.03	0.0	2.45	3.43	11.3	

$T_{1/2}^{0\nu} > 9.2 \times 10^{25}$ year (90% C.L.)

KamLAND-Zen 400 Results



Upper limit of ^{136}Xe 0νββ half life (90%C.L.)

Phase 1 : $T_{1/2}^{0\nu} > 1.9 \times 10^{25}$ year

Phase 2 : **$T_{1/2}^{0\nu} > 9.2 \times 10^{25}$ year**

Phase 1+2 : **$T_{1/2}^{0\nu} > 1.07 \times 10^{26}$ year**

Effective Majorana mass

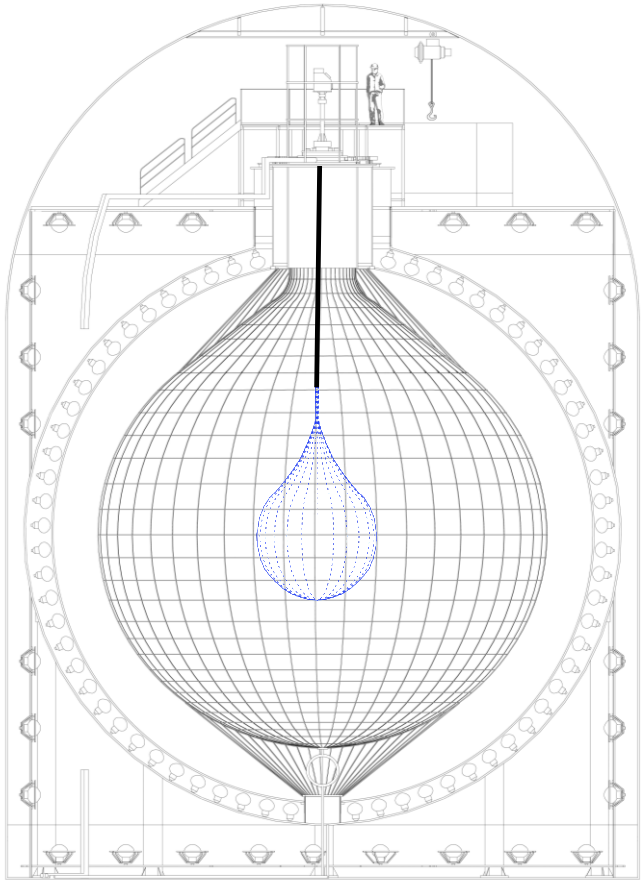
$\langle m_{\beta\beta}\rangle < 61 \sim 165$ meV

first search for below 100 meV (near IH)

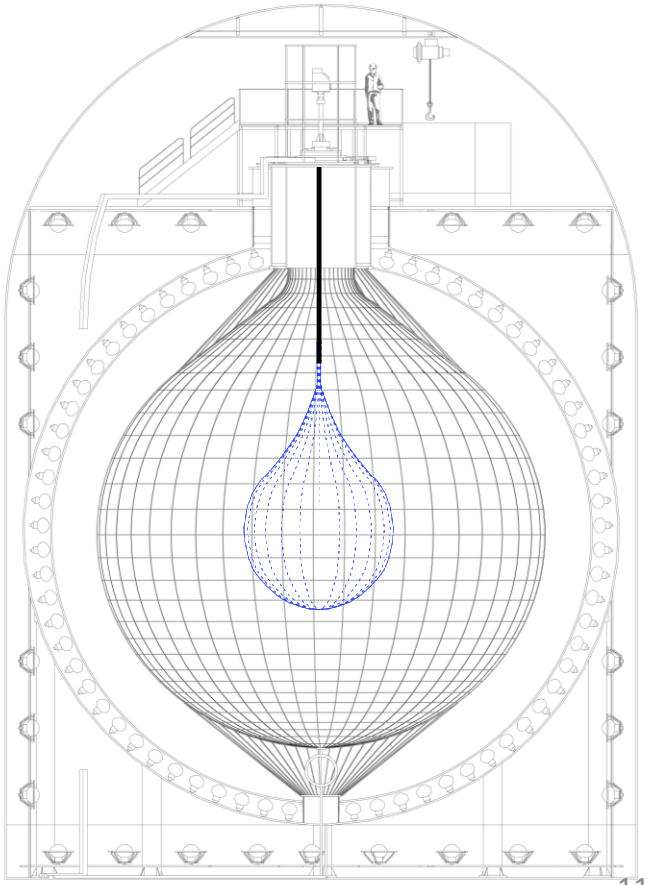
KamLAND-Zen 800

KamLAND-Zen 800

Xenon 383kg
Radius 1.54 m

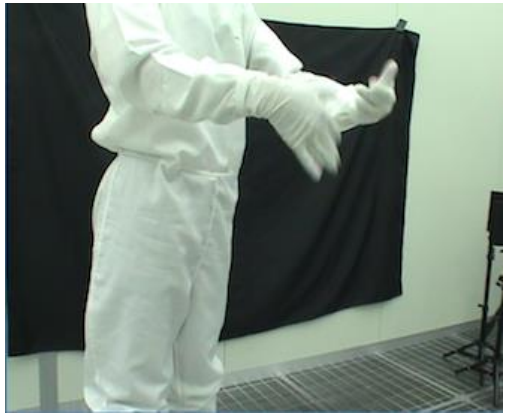


Xenon 750kg
Radius 1.92 m



KamLAND-Zen 800 updates

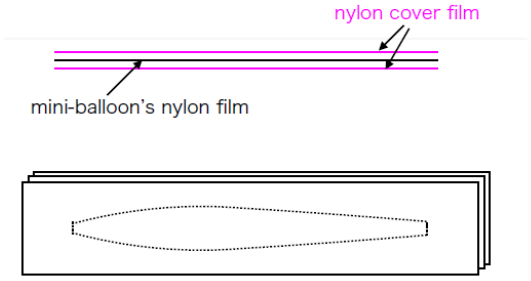
Laser Visualization



Some updated method

- Cleanup duper cleanroom by ourselves.
  (Covering HEPA filter edge)
- Wash everything by detergent, pure water, ethanol and IPA.
- Wear clean room inner cloth. (washing every time)
- Two stage clean cloth. Final cloth (working inner balloon construction) is washed every time.
- Doubled-over glove, goggle.
- More electrostatic eliminators.
- Mist generator keeps 65% humidity (in winter season).
- Covering inner balloon film.
- and more …

Film protection



Welding machine

Zen800 balloon construction

film washing

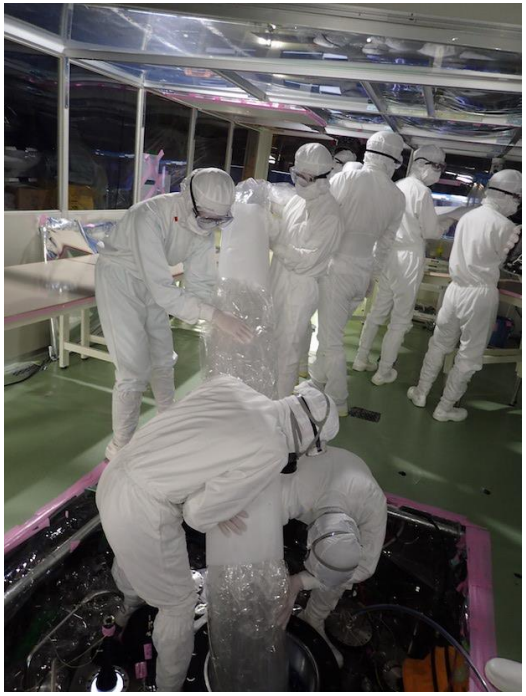
welding

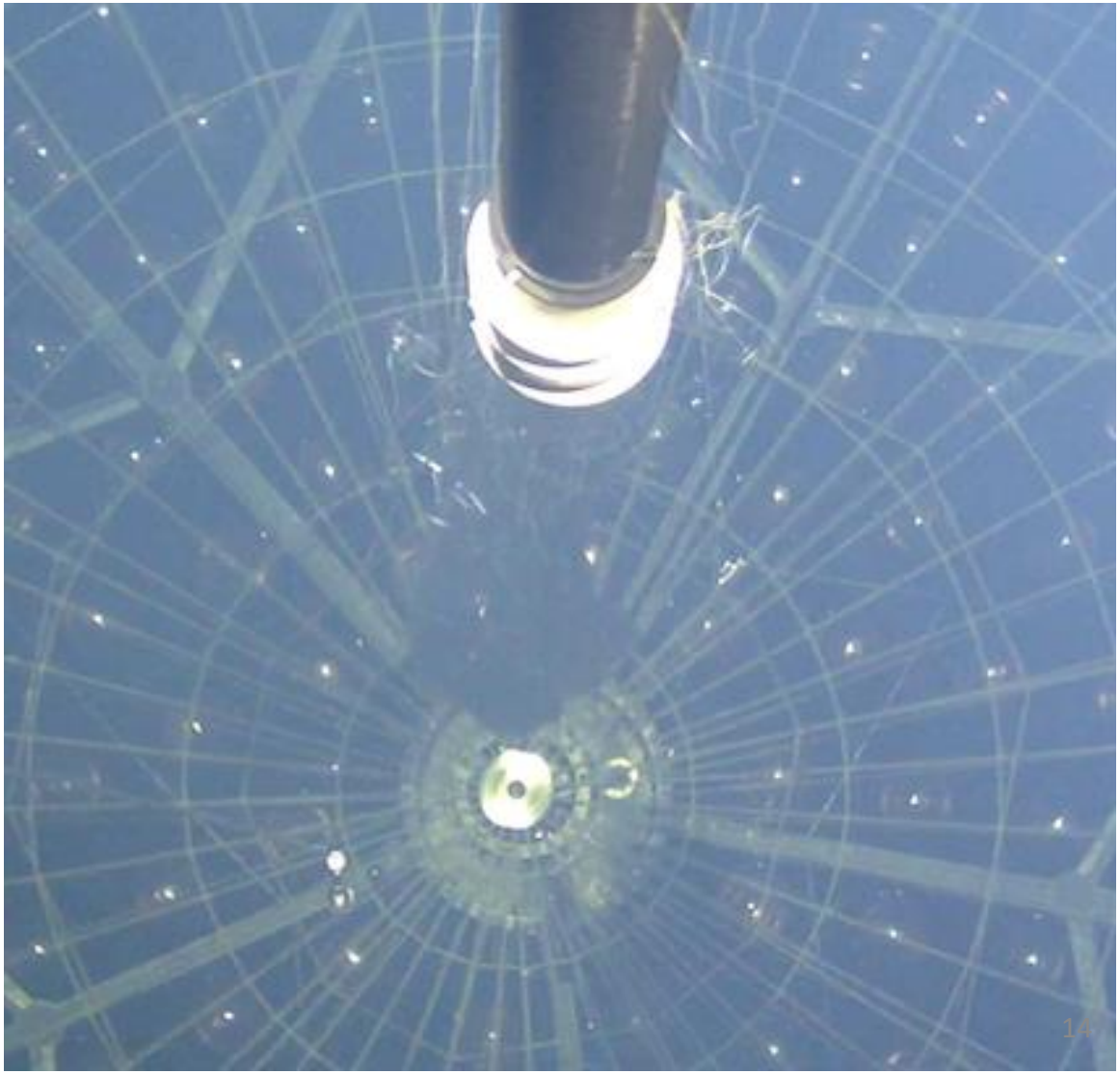
leak check & repairing

folding

delivery

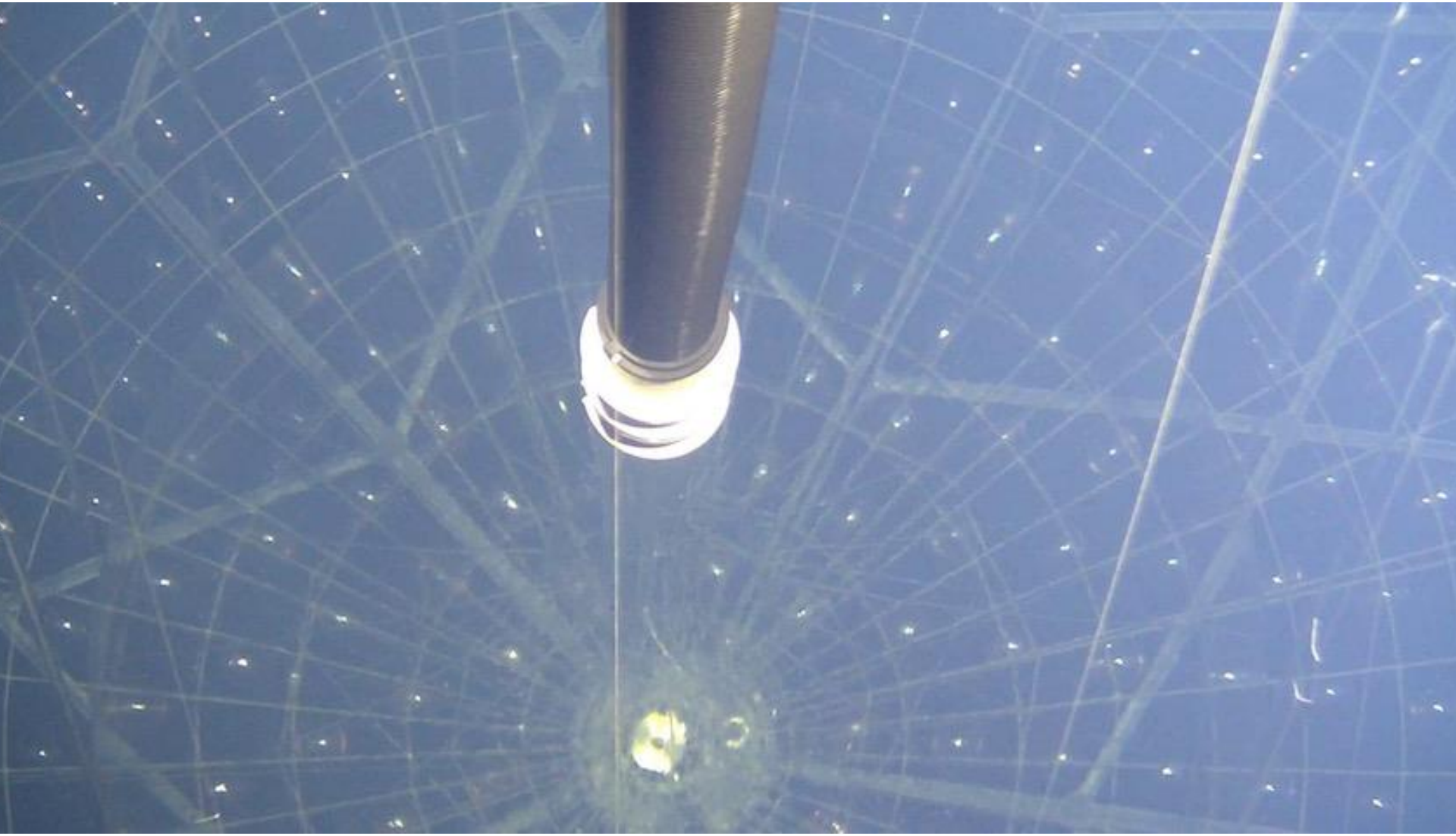
Zen800 balloon installation





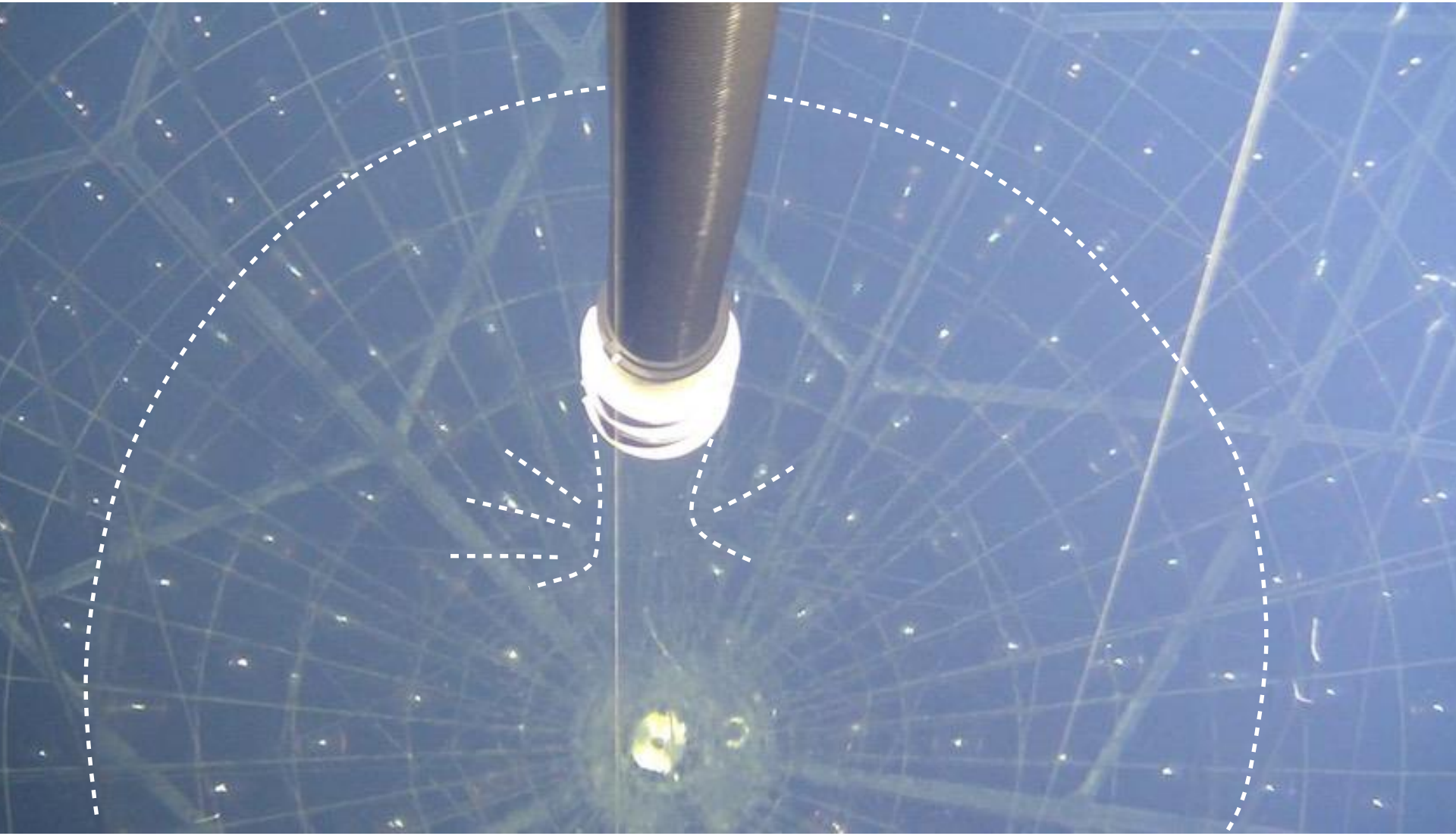

May 10 24:35
After the installation & piping connections

Dummy LS filling



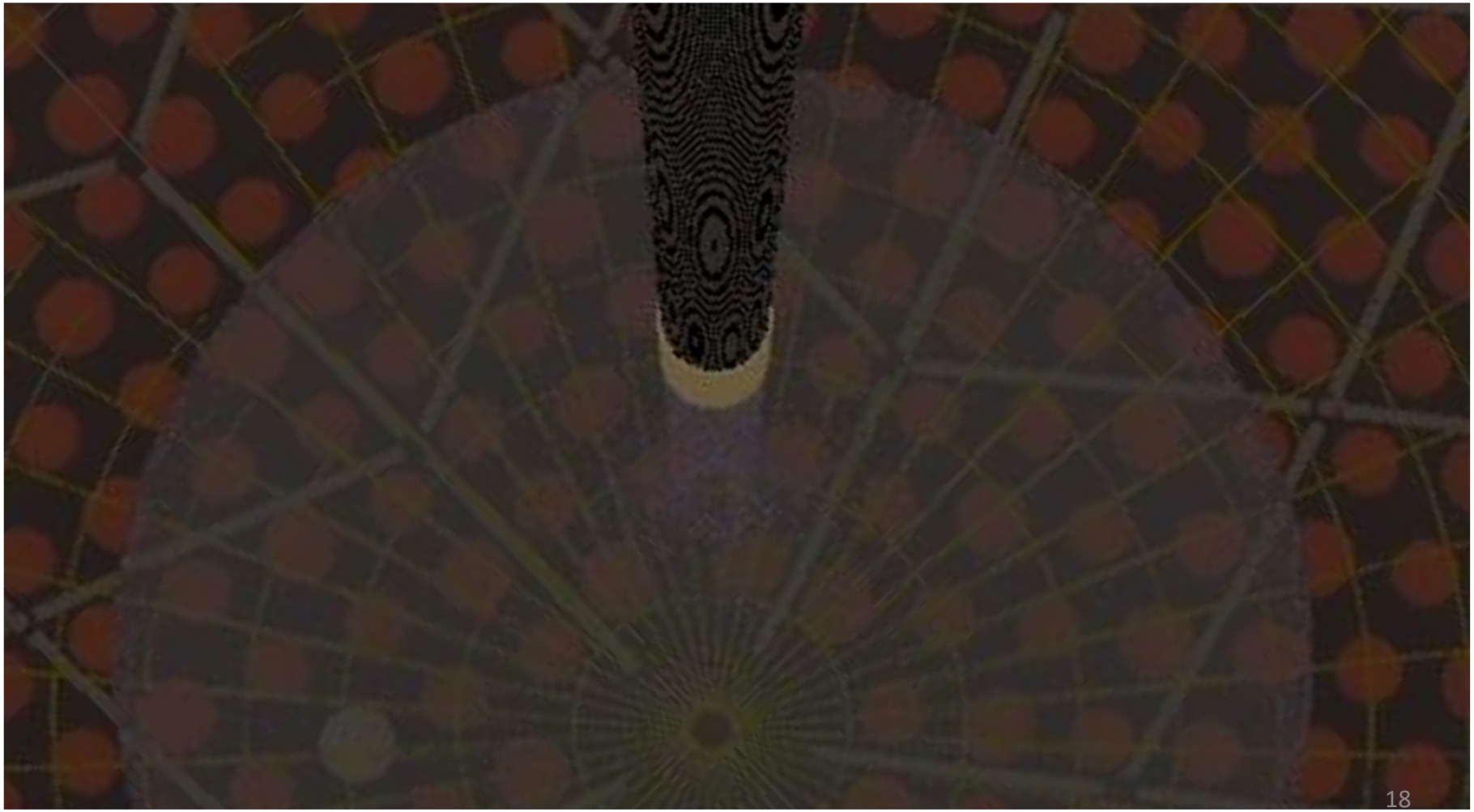
Picture after 30.5 m^3 dummy-LS filling

Dummy LS filling

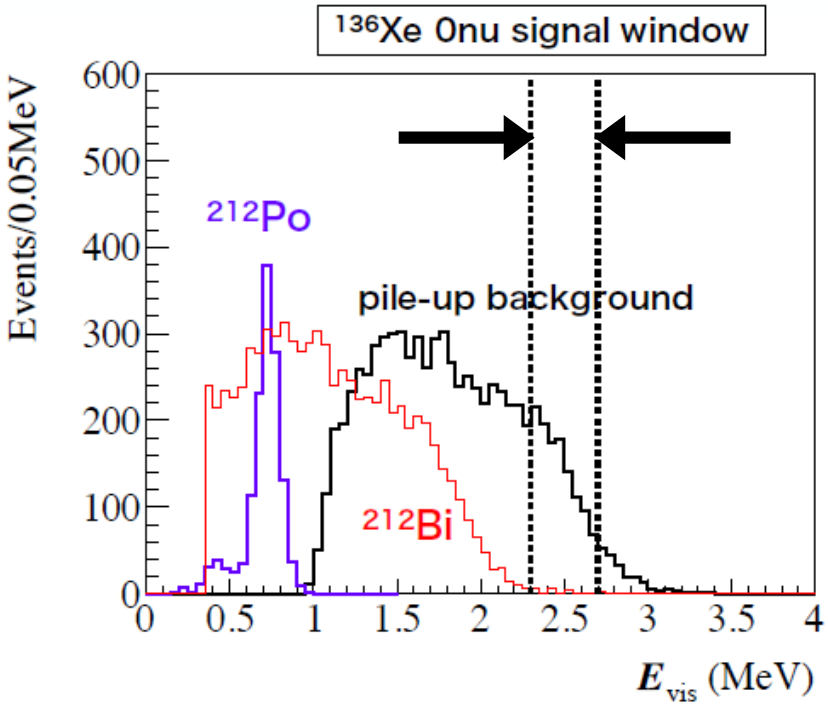


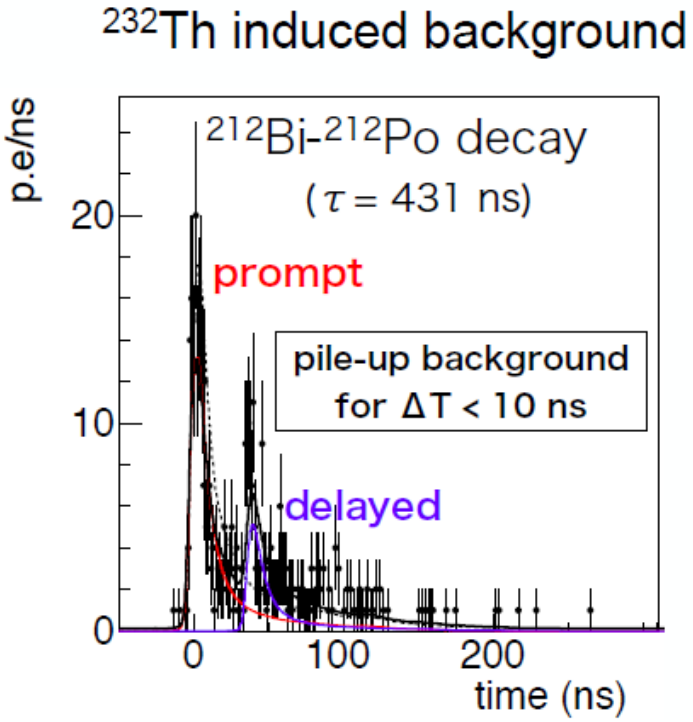
Picture after 30.5 m^3 dummy-LS filling

Optical photon ray tracing (geant4)



Background reduction



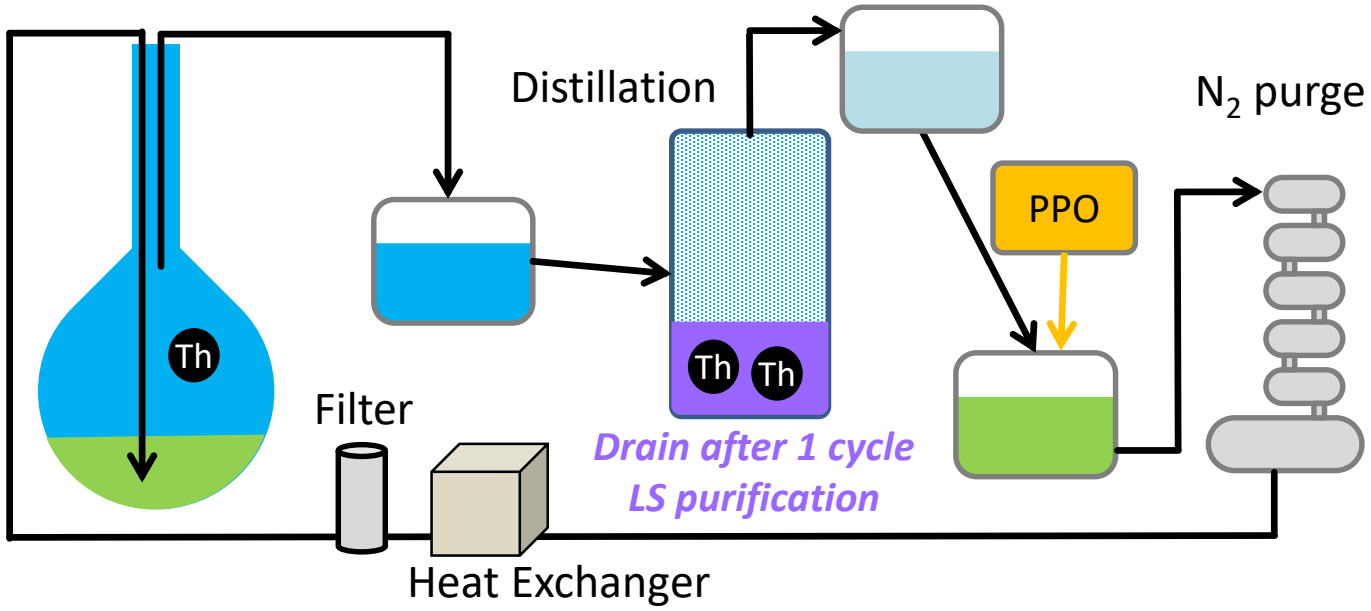


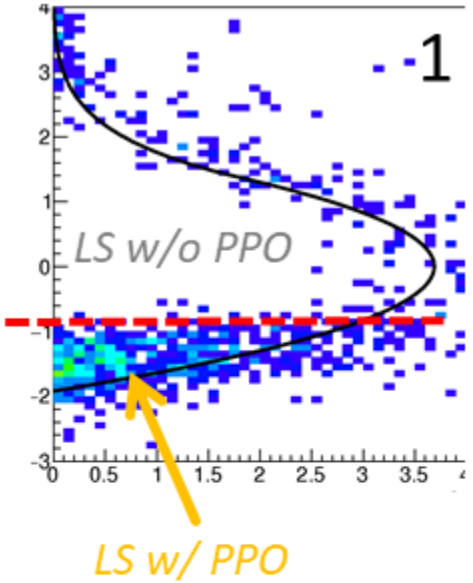
^{232}Th in Dummy-LS

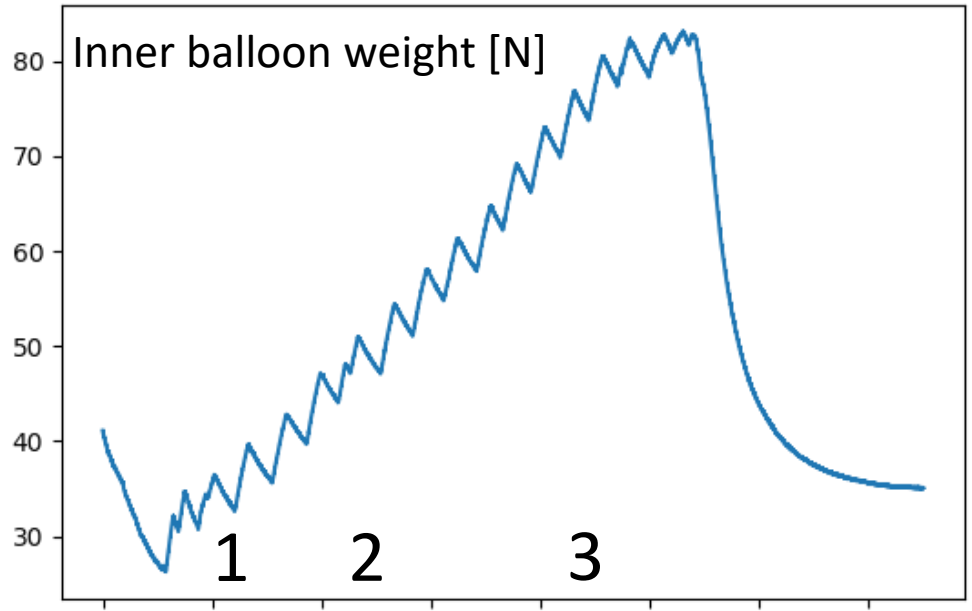
- KamLAND-Zen 400 5.9×10^{-17} [g/g]
- Our target O(10^{-16}) [g/g]
- KamLAND-Zen 800 Dummy LS O(10^{-15}) [g/g]

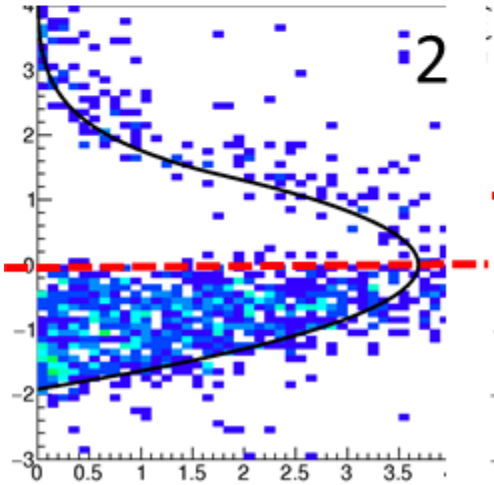
Not so bad condition, but we are now trying ^{232}Th reduction by LS distillation-circulation.

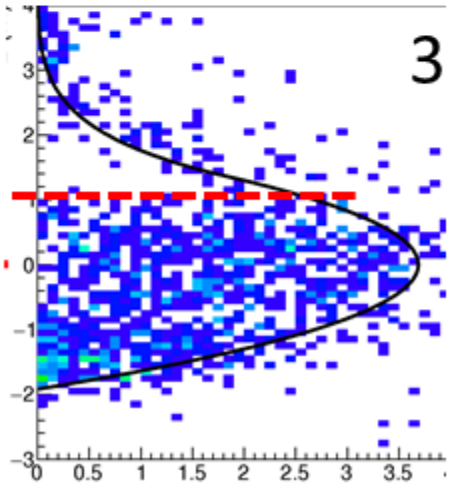
Distillation purification











Summary

- Successfully KamLAND-Zen800 inner-balloon installation.
- Distillation circulation for reducing Th.
- Filling LS has been finished.
- Now checking LS purity.
- KamLAND-Zen 800 future prospect is talked by Prof. Inoue at Oct. 23 session.