KamLAND-Zenの現状

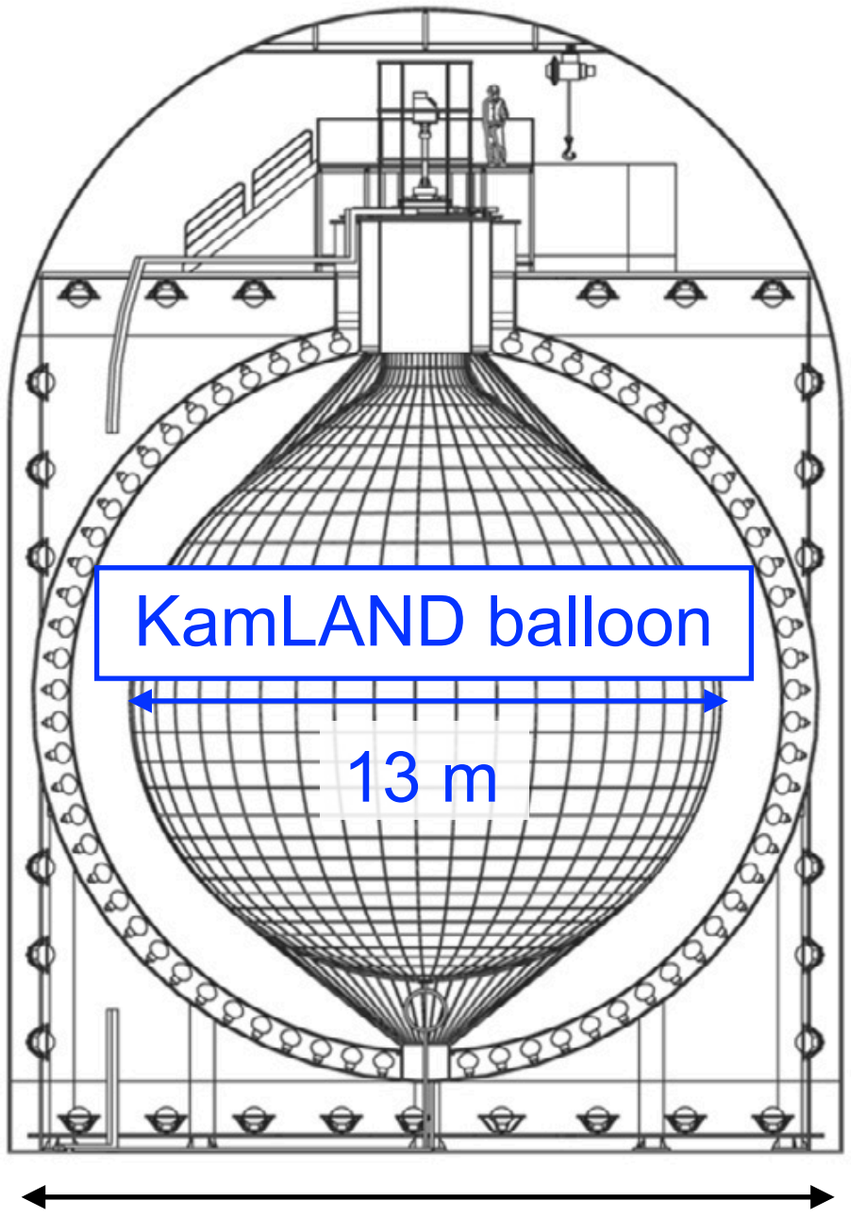
第4回 A班若手研究会

2018/11/09

東北大学
ニュートリノ科学研究センター
竹内 敦人

KamLAND

KamLAND (Kamioka Liquid scintillator Anti Neutrino Detector)



- Ultra low BG environment
- Low cosmic-ray muon rate

Inner Detector (ID)

- Liquid scintillator (~1000 ton)
  Dodecane ,PC + PPO
- Buffer oil
- Photo multiplier tubes
  - 17” Box&Line PMTs : 1325
  - 20” Venetian Blind PMTs : 554

Outer Detector (OD)

- Pure water (3200 ton)
- Photo multiplier tubes
  - Venetian Blind PMTs : 140
    + HQE-PMTs : 20

Physics

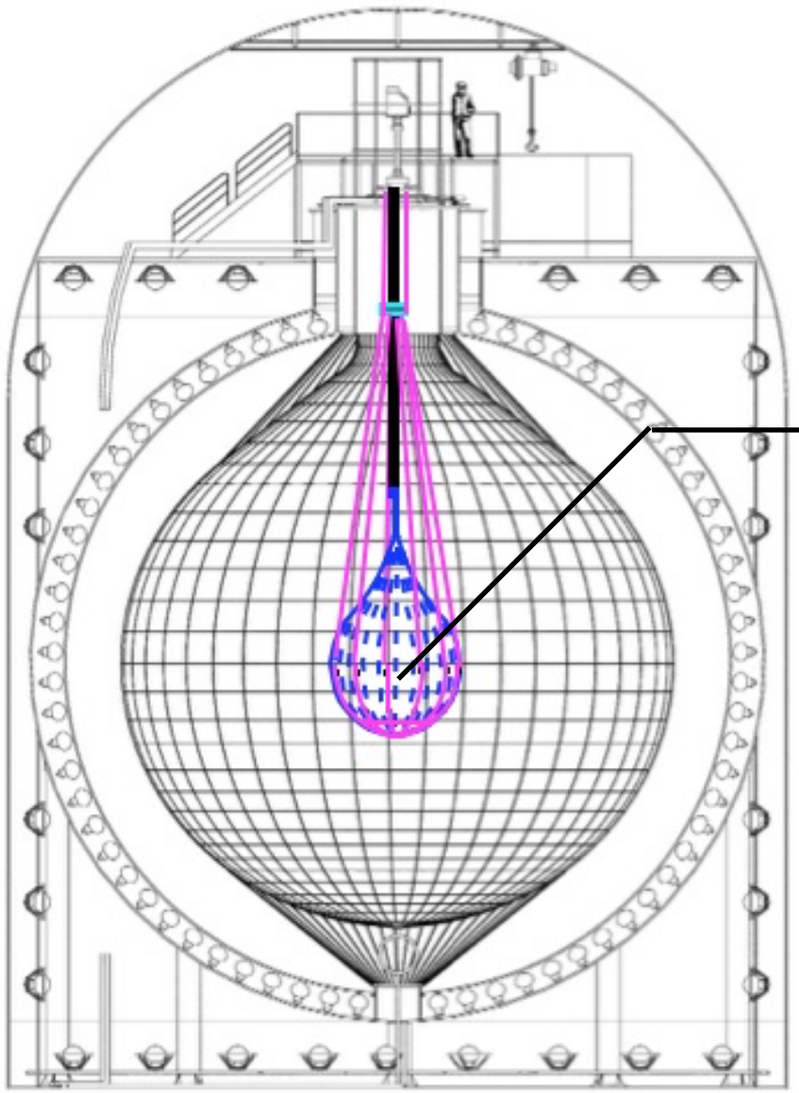
- Reactor neutrinos
- Geo neutrinos
- and so on … → 安部くんのトーク

KamLAND-Zen

KamLAND-Zen = $0\nu\beta\beta$ search w/ KamLAND

$\beta\beta$ isotope : ^{136}Xe

	^{48}Ca	^{76}Ge	^{82}Se	^{96}Zr	^{100}Mo	^{116}Cd	^{130}Te	^{136}Xe	^{150}Nd
Q-val.(MeV)	4.271	2.04	2.995	3.35	3.03	2.80	2.53	2.458	3.367
Nat.Ab.(%)	0.189	7.44	8.73	2.80	9.67	7.49	34.1	8.9%	5.6



- Isotope enrichment method
- High solubility to LS (~3.5 wt%)
- Long half-life of $2\nu\beta\beta$

Xenon loaded LS
- 90 % enriched ^{136}Xe
- packed in mini-balloon

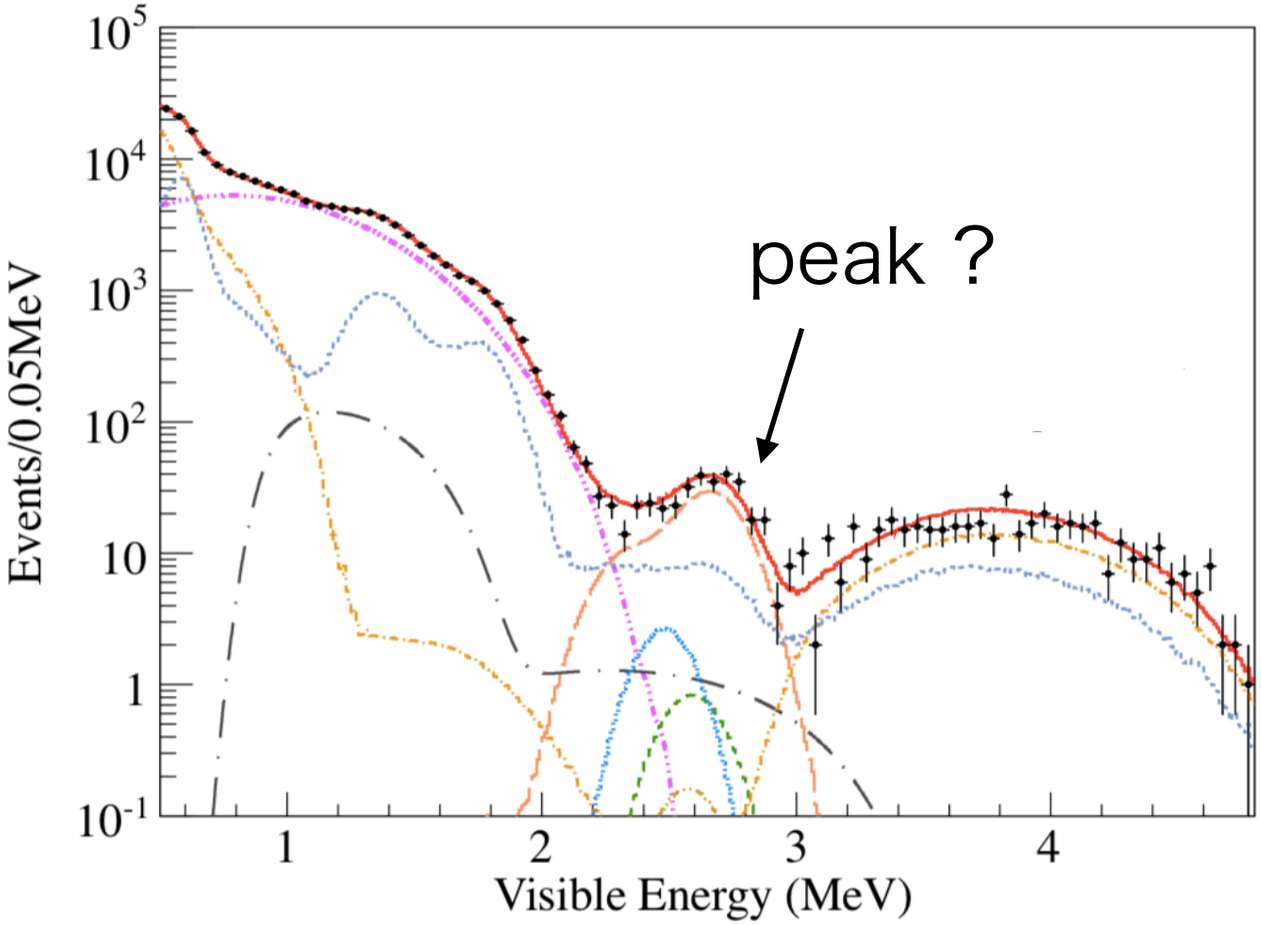
Advantages of using KamLAND
- Lower cost and quick start
- Easily scalable
- Flexible operation
- Multi purpose

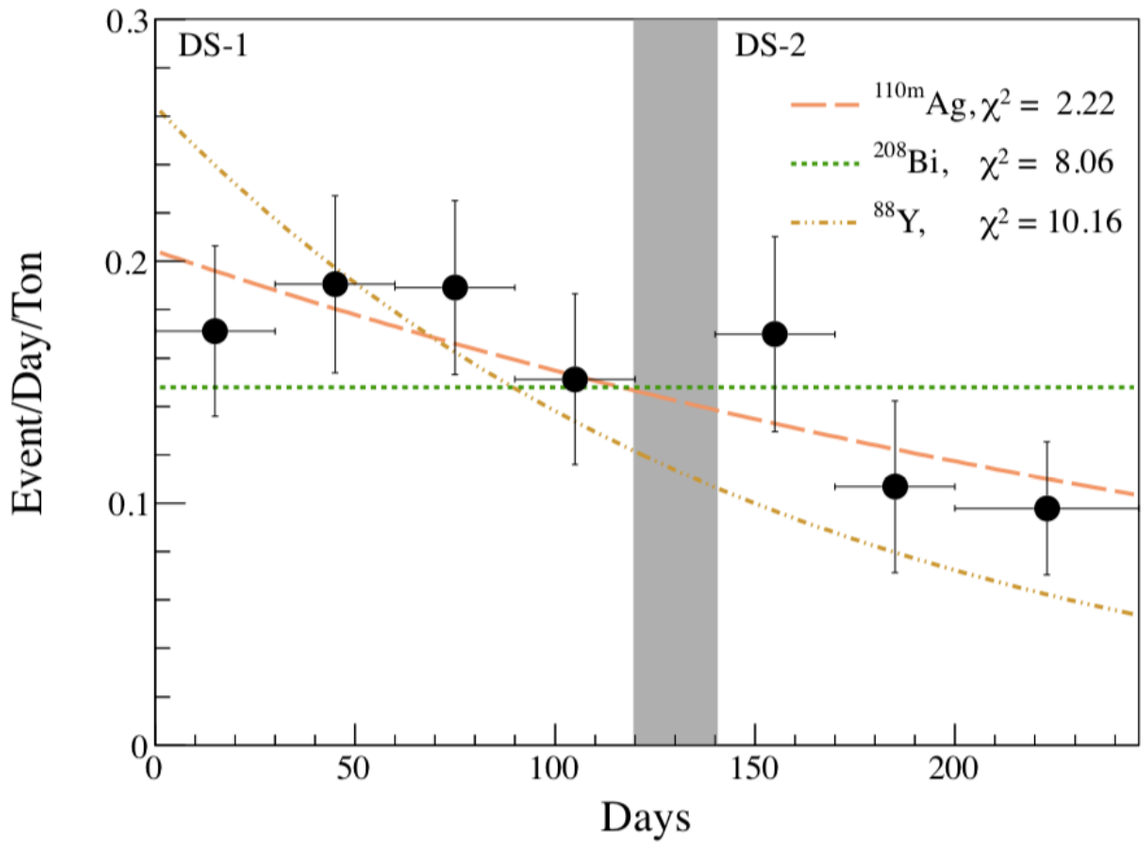
KamLAND-Zen 400

KamLAND-Zen 400

KamLAND-Zen 400 phase 1 : 2011/10 ~
(w/ Xe 320 kg)

preparation : about 2 years
(lower cost and quick start)





$0\nu\beta\beta$ region was dominated by ^{110m}Ag (τ = 360 days, Q = 3.01 MeV) .

Suspects

- Spallation product of Xe?
- Surface contamination of mini-balloon supporter?

→ Xe and LS was distilled. (flexibility)

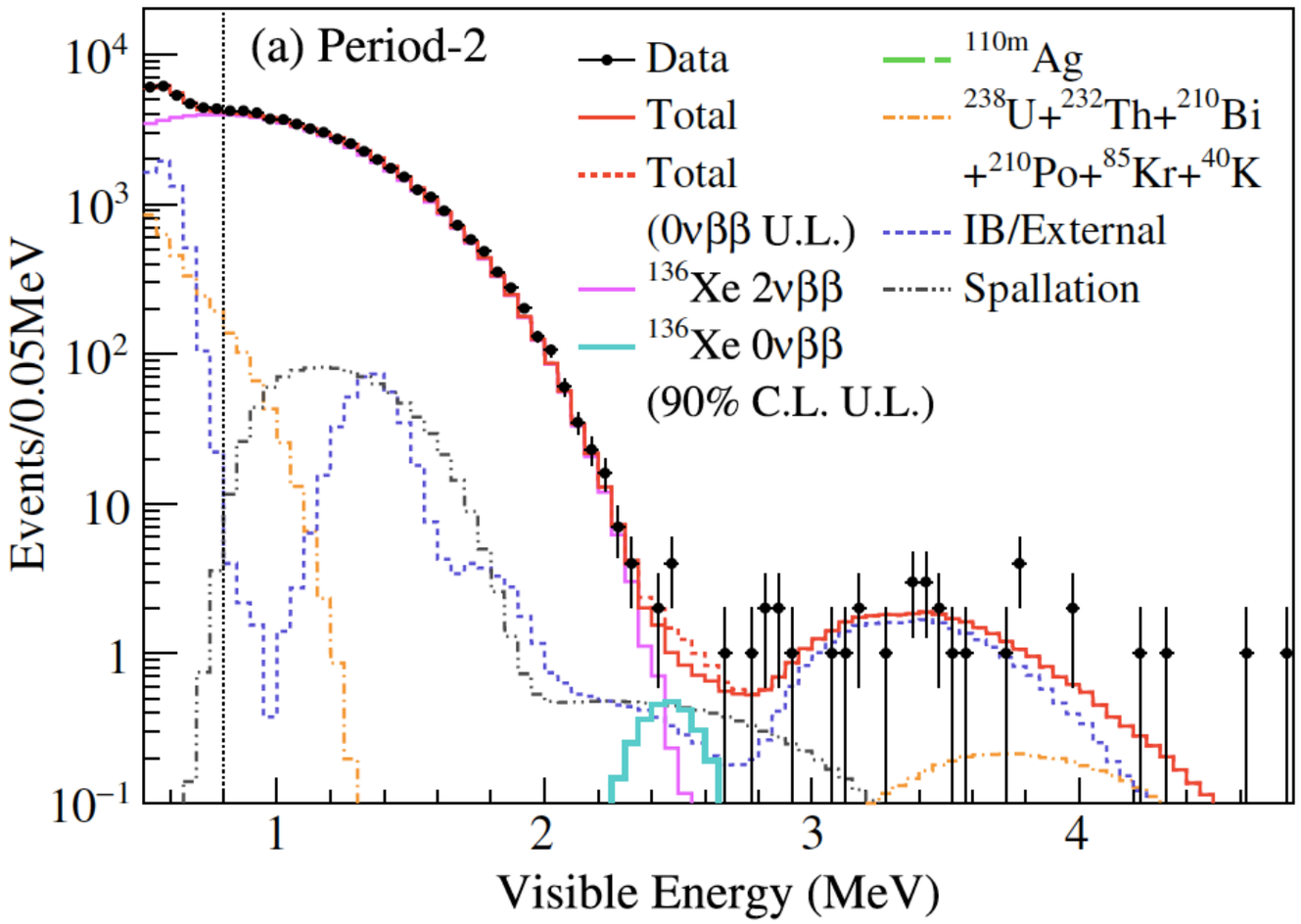
$(T^{0\nu}_{1/2} > 1.9 \times 10^{25}\ \mathrm{yr})$

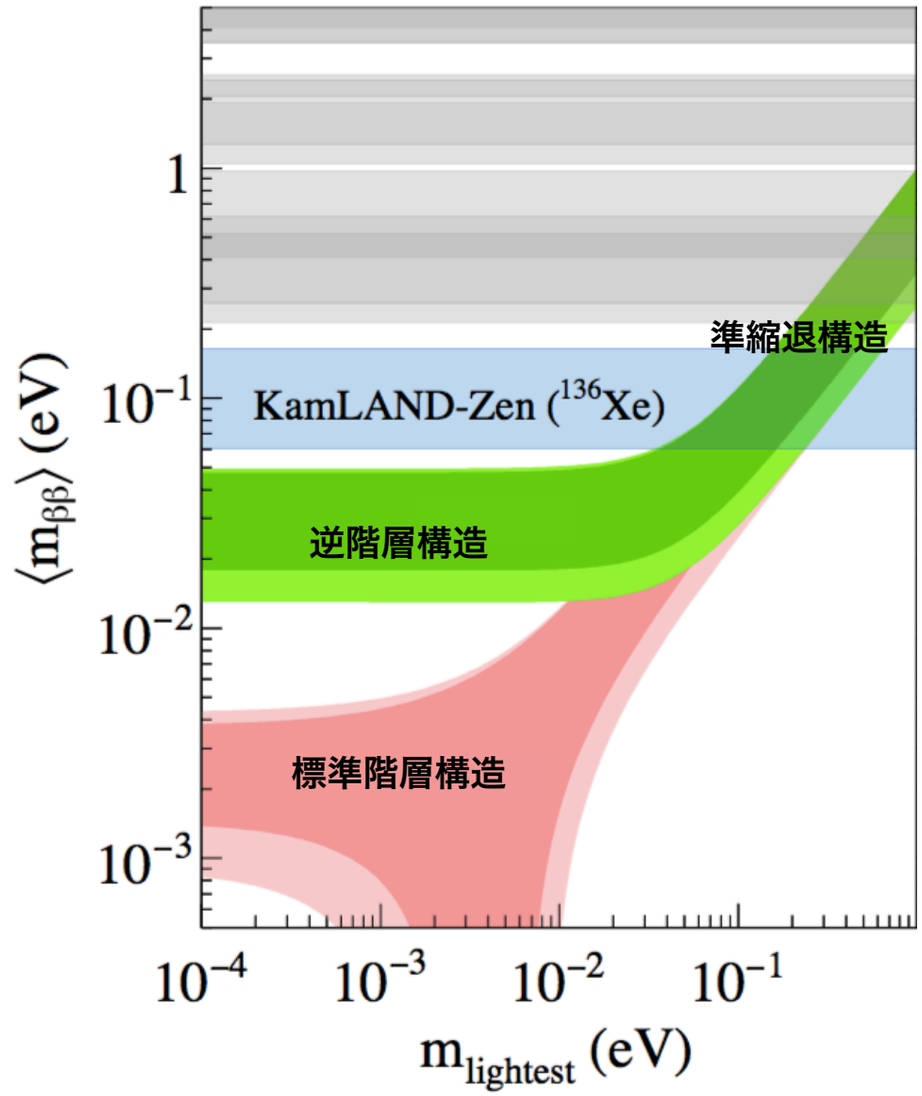
KamLAND-Zen 400

After 1.5 years purification …

KamLAND-Zen 400 phase 2 : 2013/11 ~

(w/ Xe 380 kg)





phase 1 + phase 2

- Half-life of ^{136}Xe $0\nu\beta\beta$: $T^{0\nu}_{1/2} > 1.07 \times 10^{26}$ yr (90% C.L.)
- Effective Majorana mass : $\langle m_{\beta\beta} \rangle < 61 - 165$ meV

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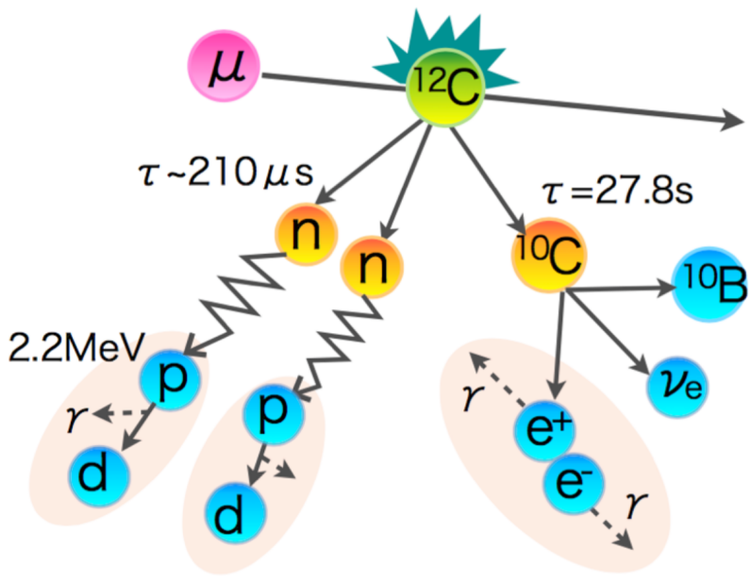
Most strictly limited in the world!

Backgrounds in KamLAND-Zen 400

- ^{10}C (spallation product)



Need BG reduction

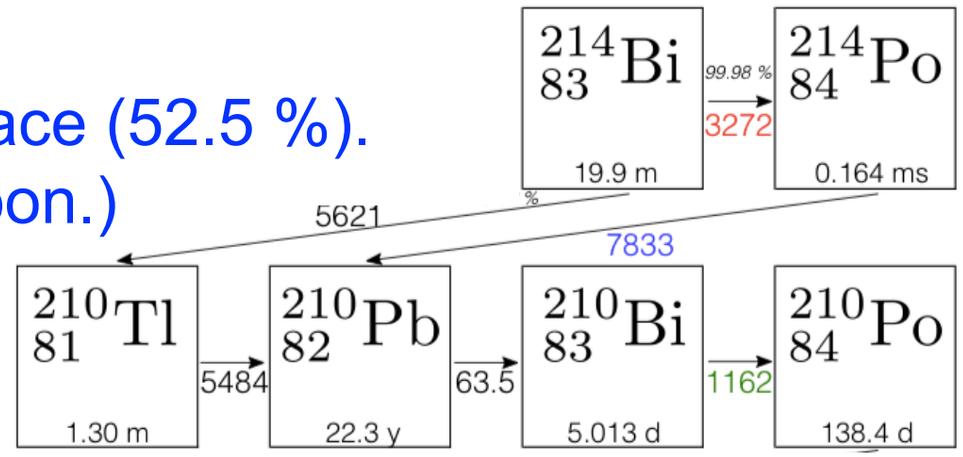
Tag : triple coincidence of μ - n - ^{10}C(β+ decay)
- efficiency = 64 ± 4 %

Lower than estimation because of high rate after-pulse.

- ^{214}Bi on balloon surface (^{214}Bi : daughter of ^{238}U, stems from dust)

Tag : delayed coincidence of ^{214}Bi(β decay)-^{214}Po(α decay)
- efficiency = 99.95 ± 0.01 % (events in LS)

⟷ Efficiency is lower on the balloon surface (52.5 %).
(Energy of α reduces because of balloon.)

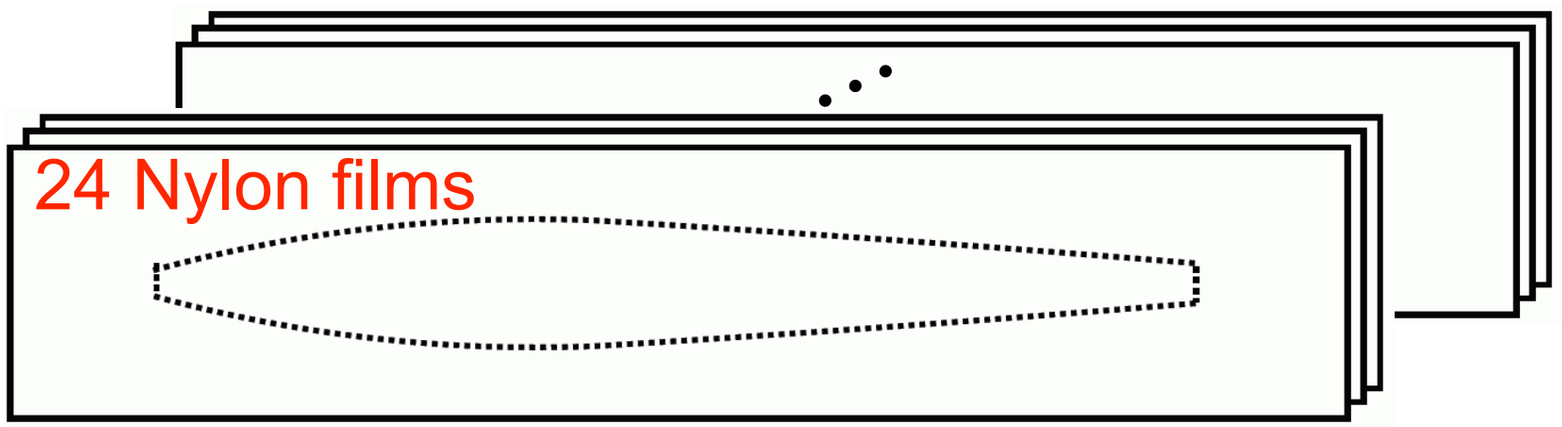


- $2\nu\beta\beta$

Need energy resolution improvement
→ KamLAND2-Zen

KamLAND-Zen 800

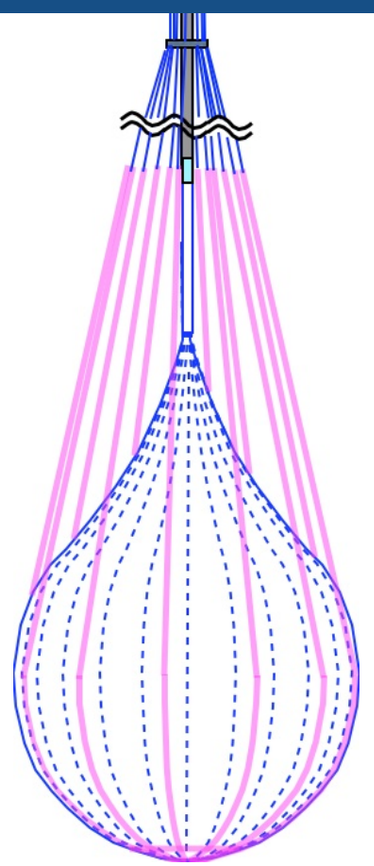
Mini-balloon Fabrication for Zen 800



thickness : 25 μm

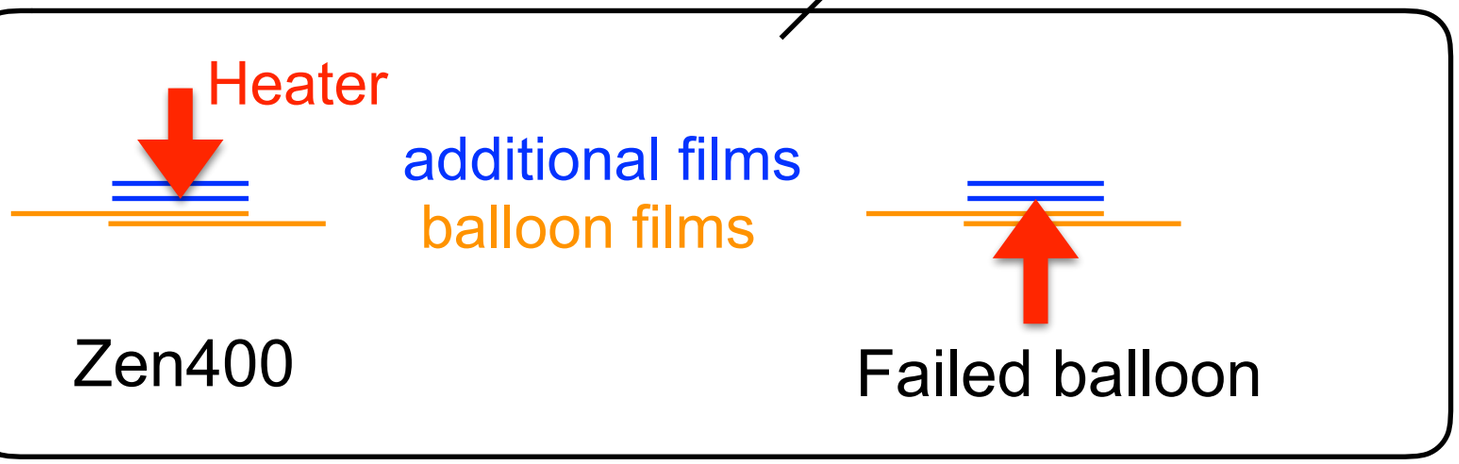
U: 2×10^{-12} g/g, Th: 6×10^{-12} g/g, $_{nat}K < 1\times10^{-7}$ g/g

Heat welding



R : 1.54 m → 1.92 m
(Scalability)

Film washing → Film cutting → Heat welding → He leakage check

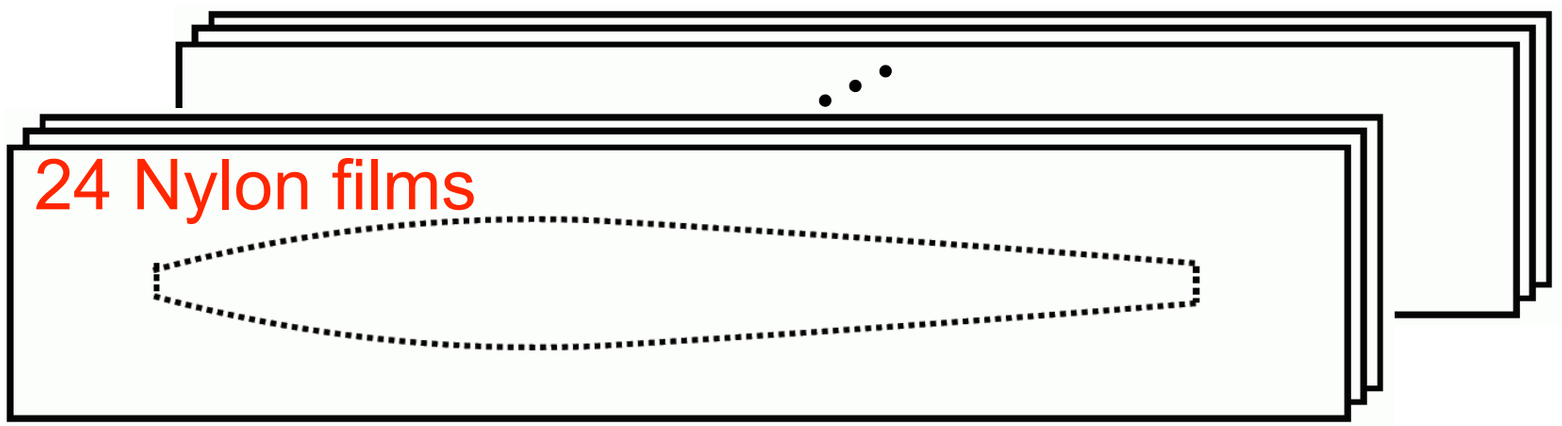


To keep balloon clean…

- made in class 1 super clean room.
- wear clean suits, glasses and gloves.
- cover Nylon films for mini-balloon films.

Washing method of supporter was also changed. → 三宅くんのトーク

Mini-balloon Fabrication for Zen 800



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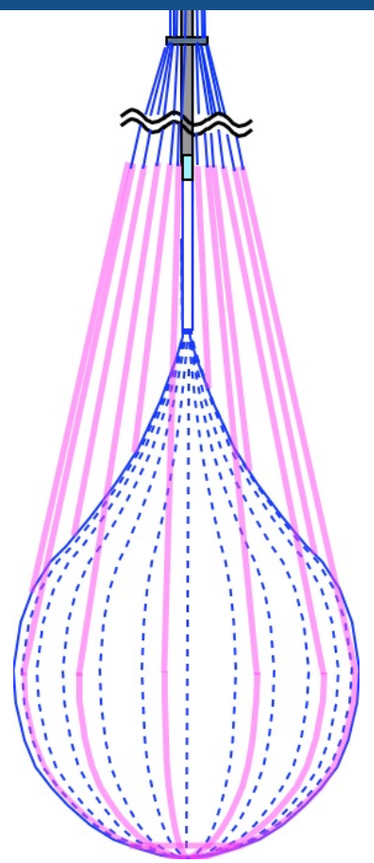

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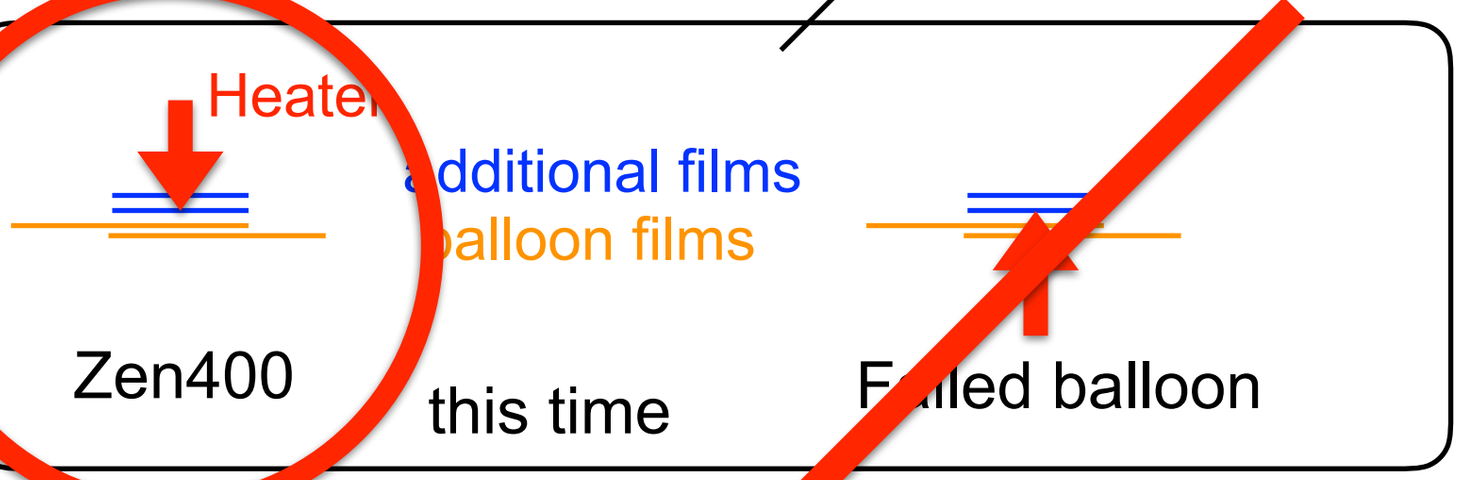

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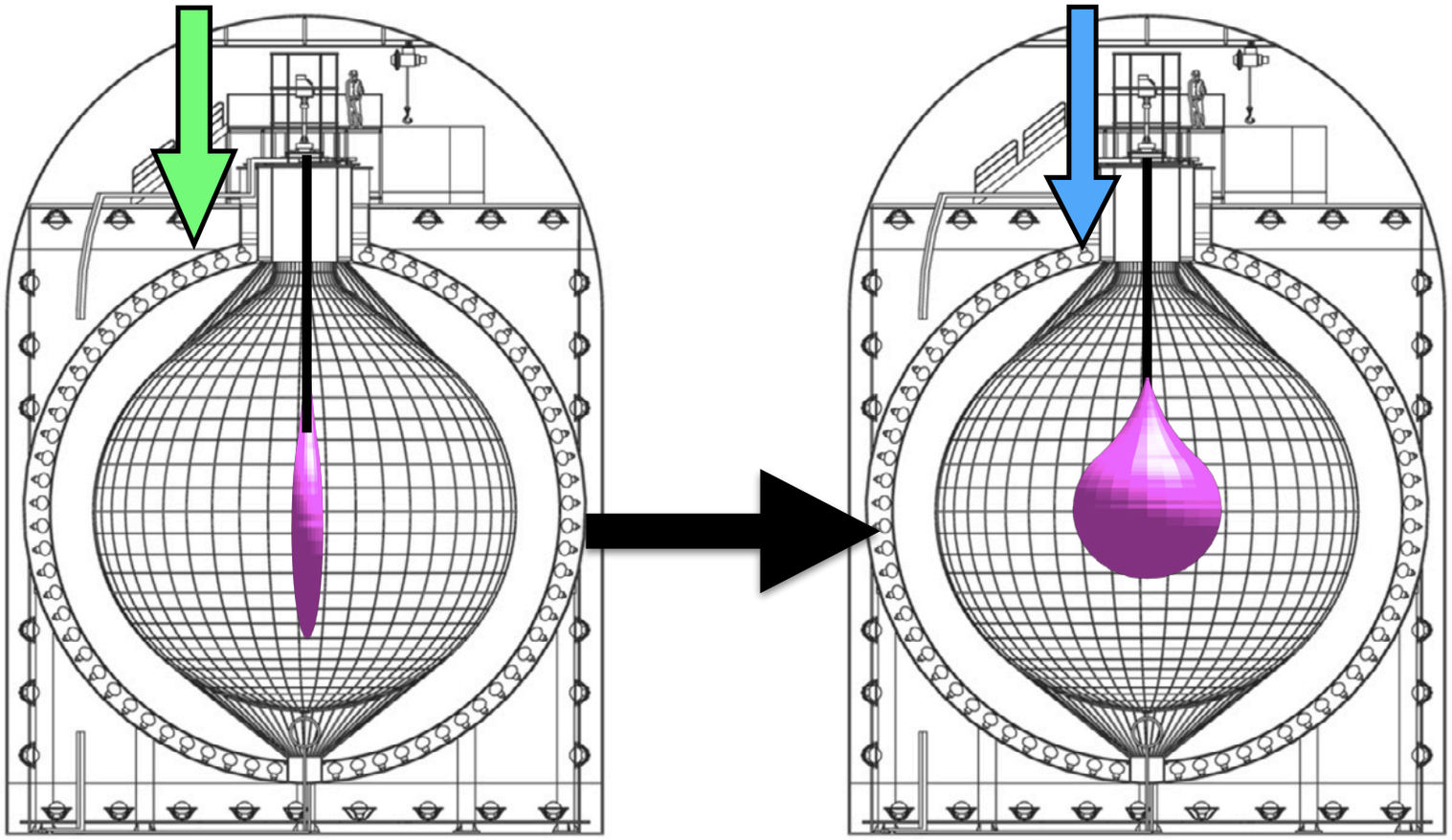
Mini-balloon Installation

Folded mini-balloon

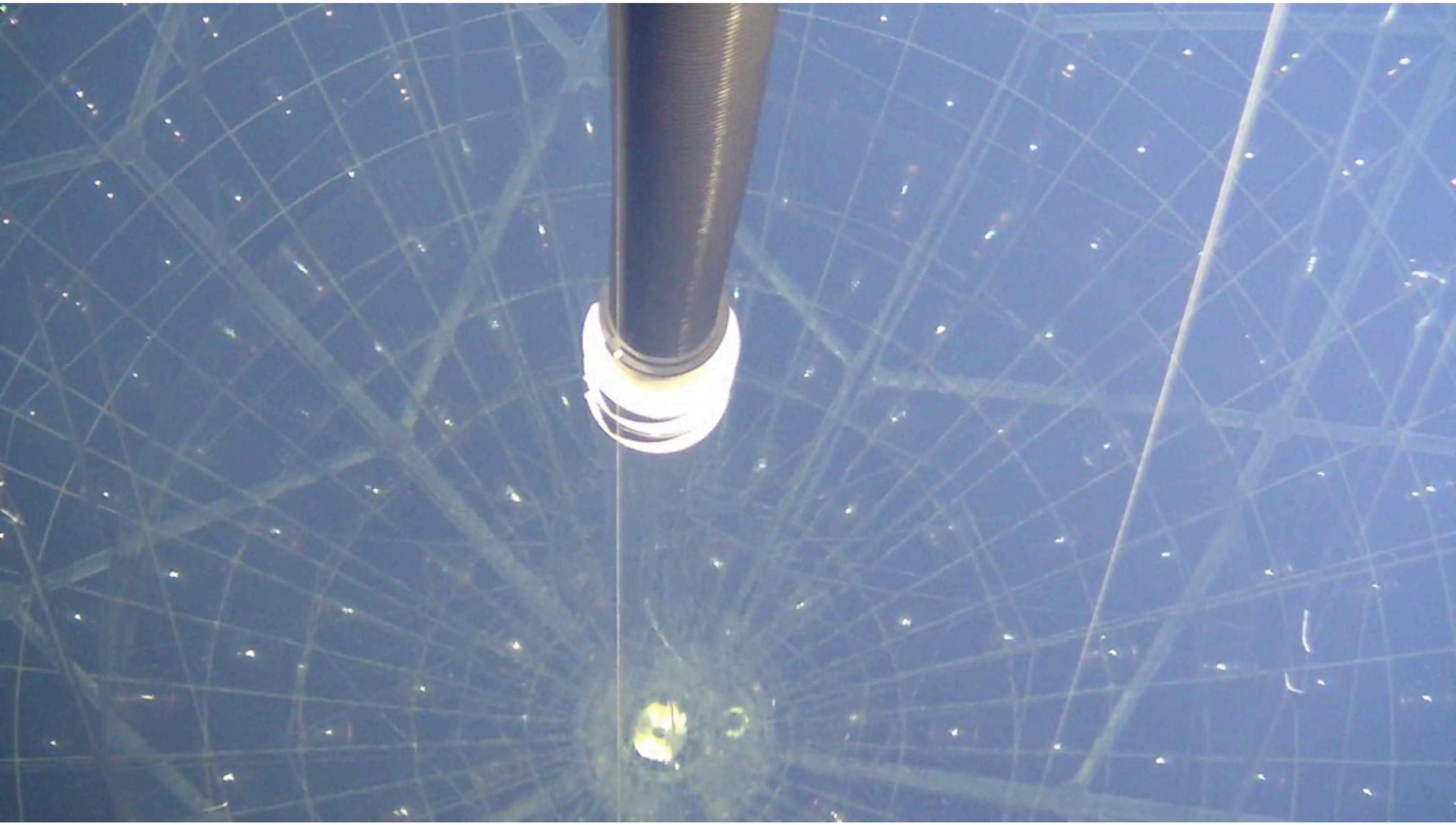
LS w/o Xe



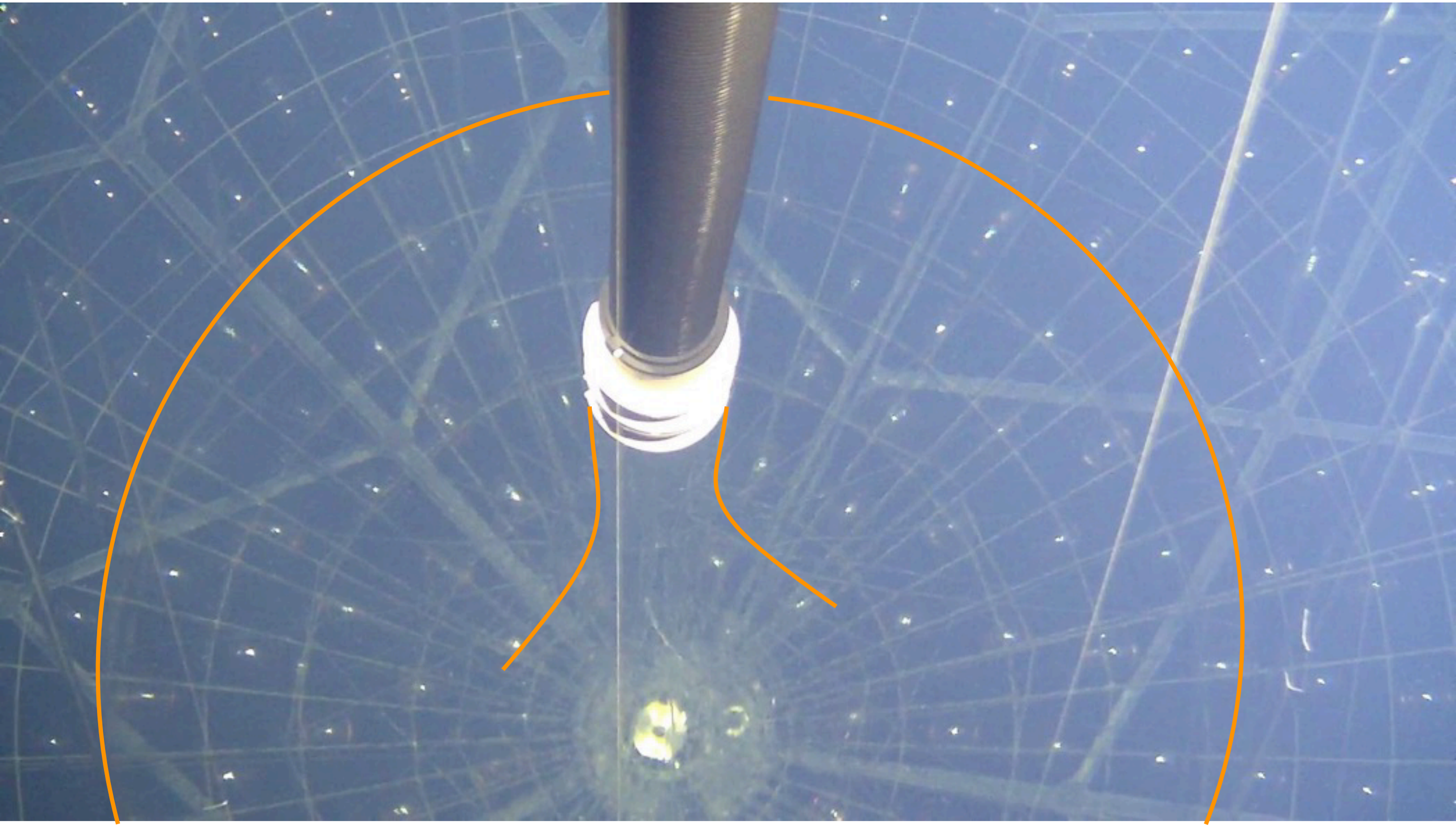
- Leakage check
- BG evaluation

We installed mini-balloon in KamLAND successfully!

Mini-balloon Installation

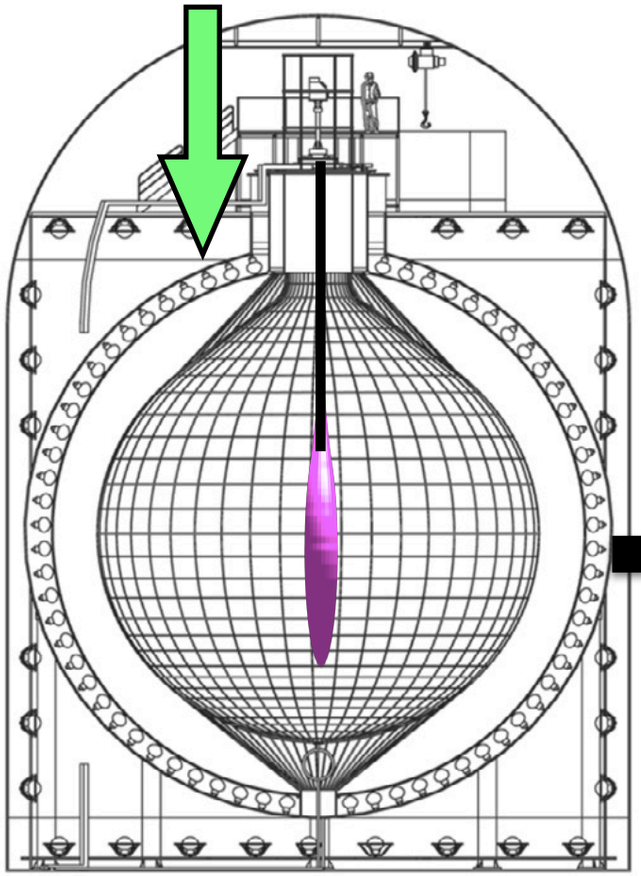


Mini-balloon Installation

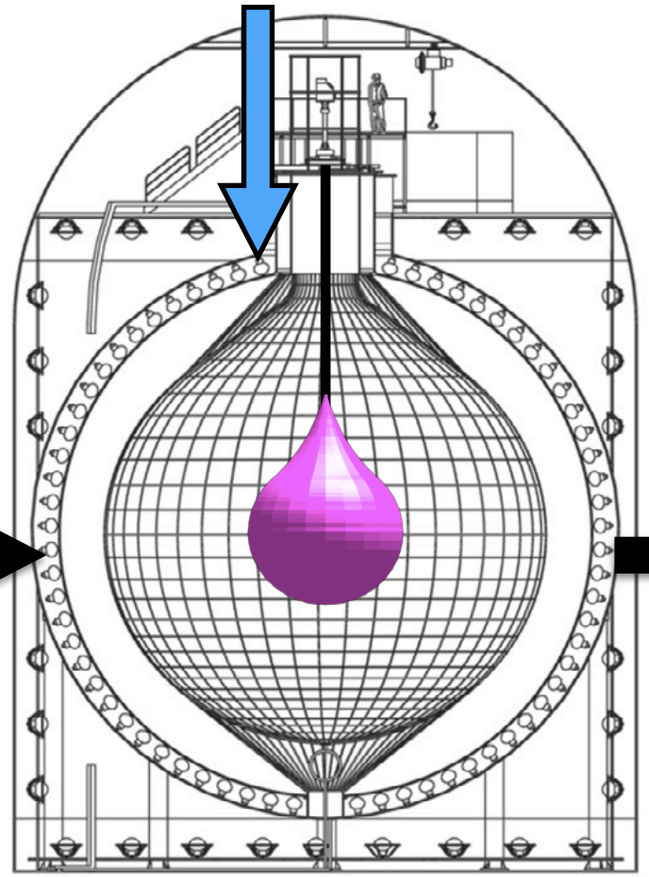


Mini-balloon Installation

Folded mini-balloon

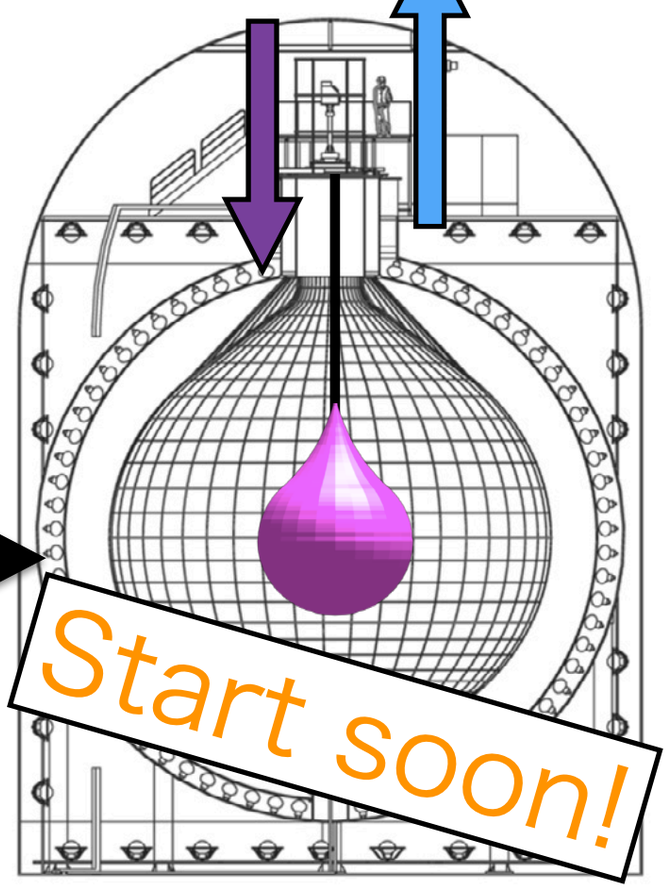


LS w/o Xe



LS w Xe

LS w/o Xe



W/ ~ 750 kg Xe

- Leakage check
- BG evaluation

↓

- LS distillation

Target :

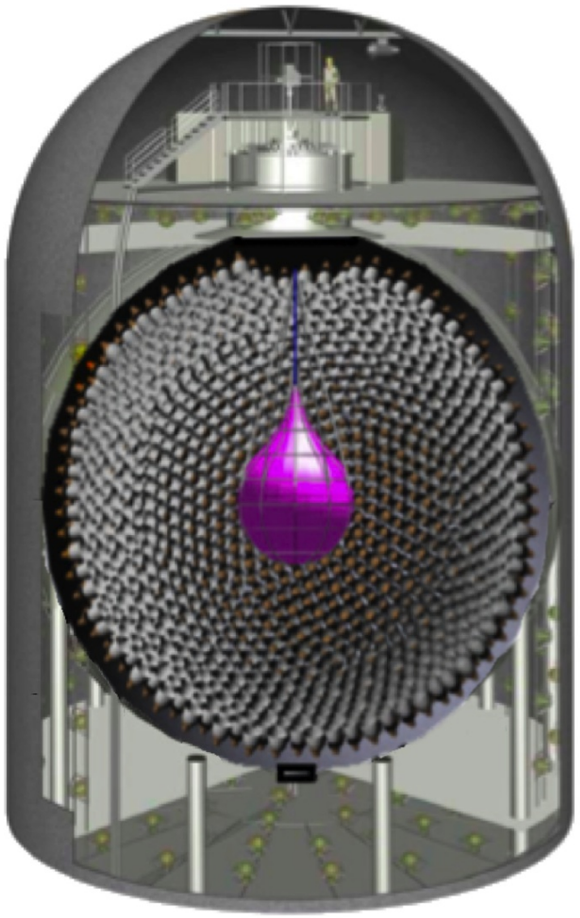
$< m_{\beta\beta} >$ ~ 40 meV

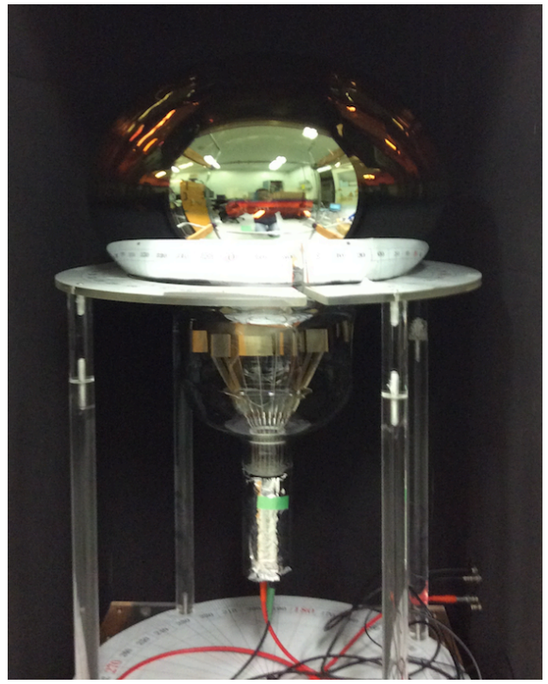
We installed mini-balloon in KamLAND successfully!

Future Plan (KamLAND2-Zen)

KamLAND2-Zen

KamLAND2 : Detector upgrade to improve energy resolution





- New-LS → light collection × 1.4

  Brighter and high transparency

- Winstone cone → light collection × 1.9

  larger coverage

- HQE-PMT → light collection × 1.8

  η = 22% → 30 %, efficient ϕ = 17”→ 20”

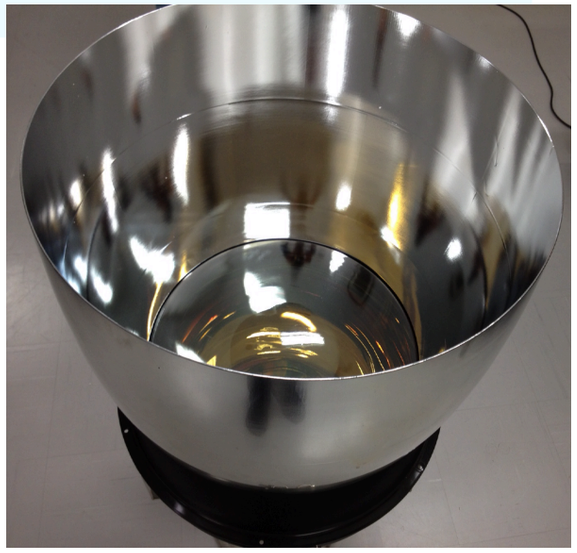
- 1000 kg Xenon

σ(Q) = 4 % → ~ 2 % ($2\nu\beta\beta$ BG decrease to < 1/10)

Target : < $m_{\beta\beta}$ > ~ 20 meV / 5 yrs

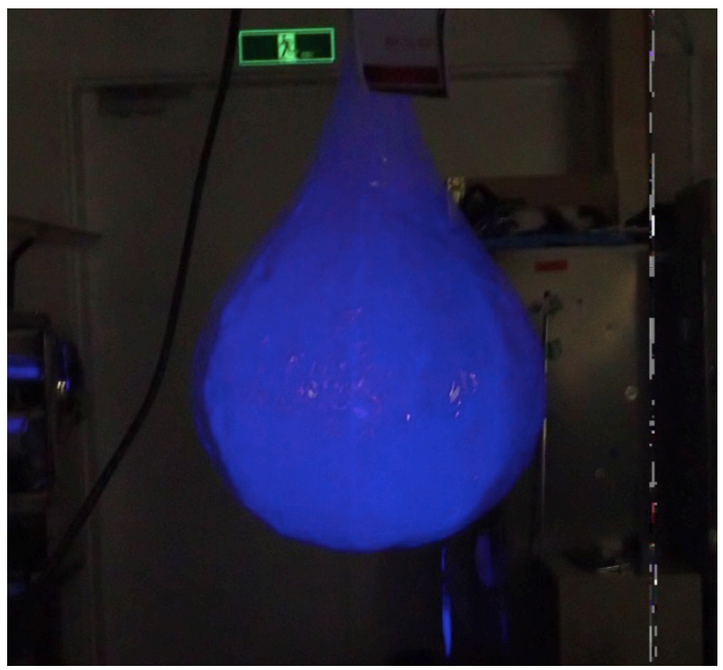
R&D is on going !

- Evaluation of LAB-LS (和田くんのトーク)
- Optimization of Winstone cone mirror
- BG reduction w/ HQE-PMT & new DAQ circuit



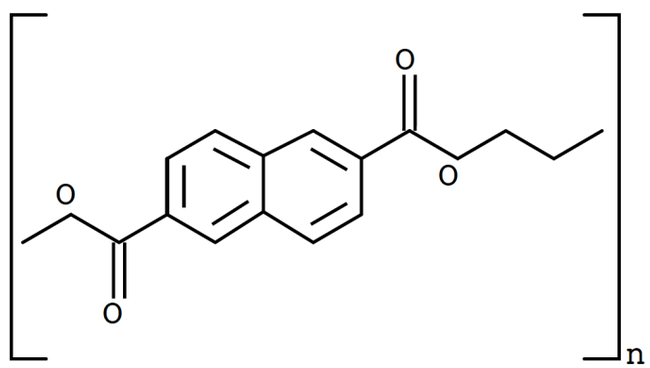
KamLAND2-Zen

For further BG reduction …



<u>Scintillation balloon</u>

→ 99.95 % of ^{214}Bi on surface can be tagged.



PolyEthylene Naphthalate

<u>New hit trigger scheme</u>

- Trigger on afterpulse is reduced by local hit.

① PMT hit (time window = 40 ns)

Differential of waveform > threshold (Differential hit)

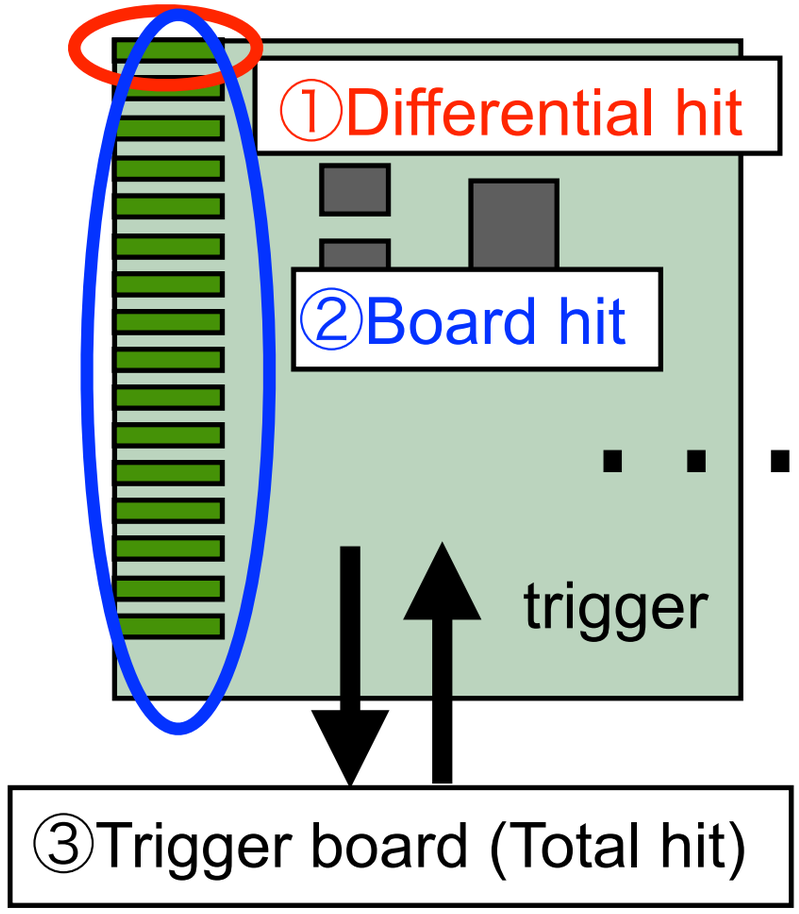
② Board hit (local hit)

The # of hit PMTs on a DAQ circuit board > threshold
(= the # of hit PMTs in local 16 PMTs (①))

③ Total hit

The # of board hits (②) > threshold

Data taking trigger



<u>Influence of after pulse is reduced w/ shorter time window.</u>