Status of the KamLAND-Zen experiment

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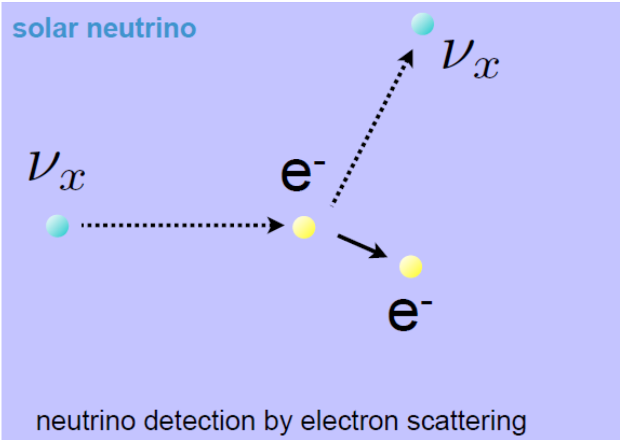
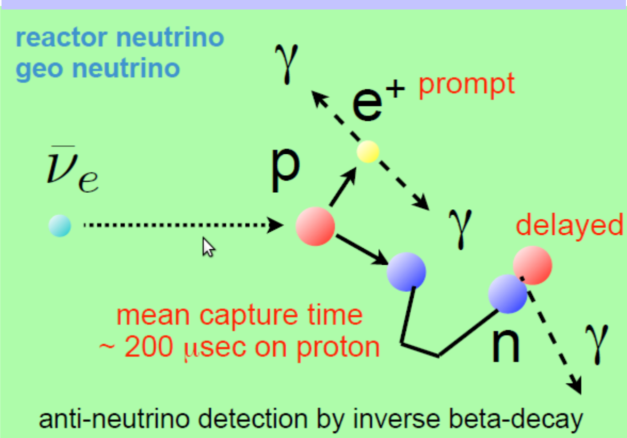
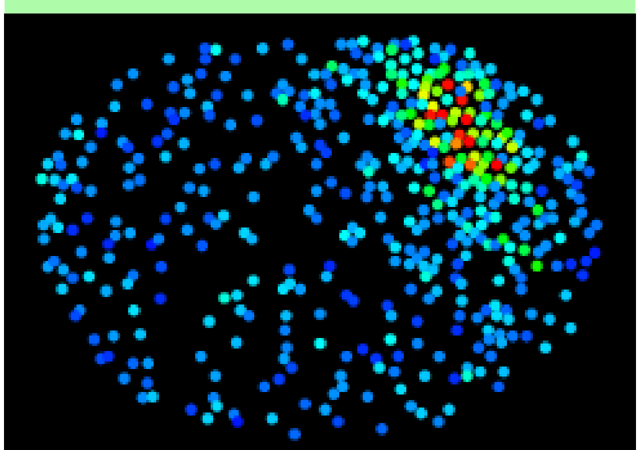
(for the KamLAND-Zen collaboration)

12th International Conference on Topics in Astroparticle and Underground Physics

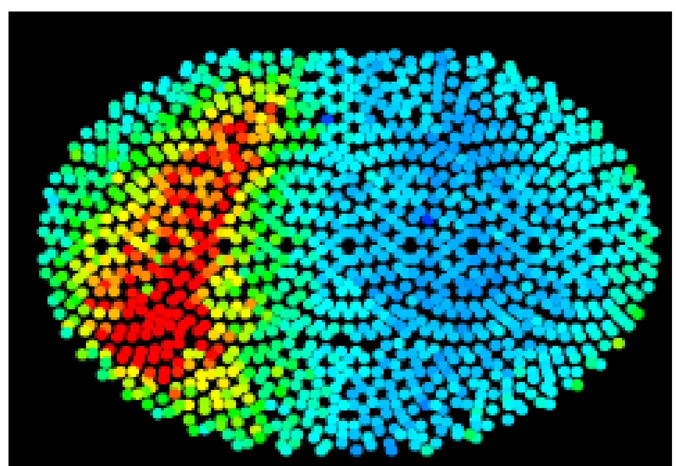
KamLAND – 1kton liquid scintillator underground detector

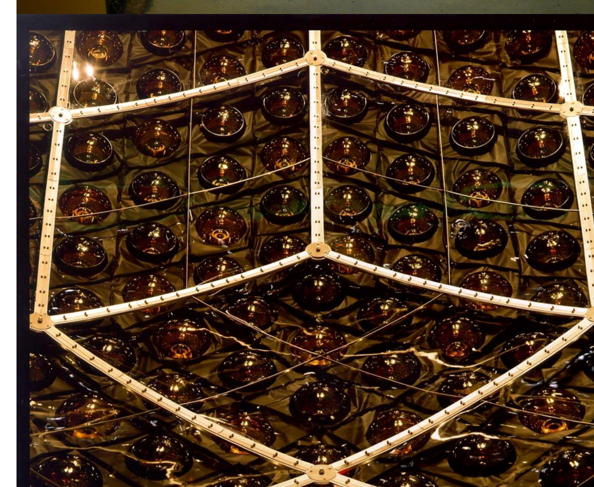






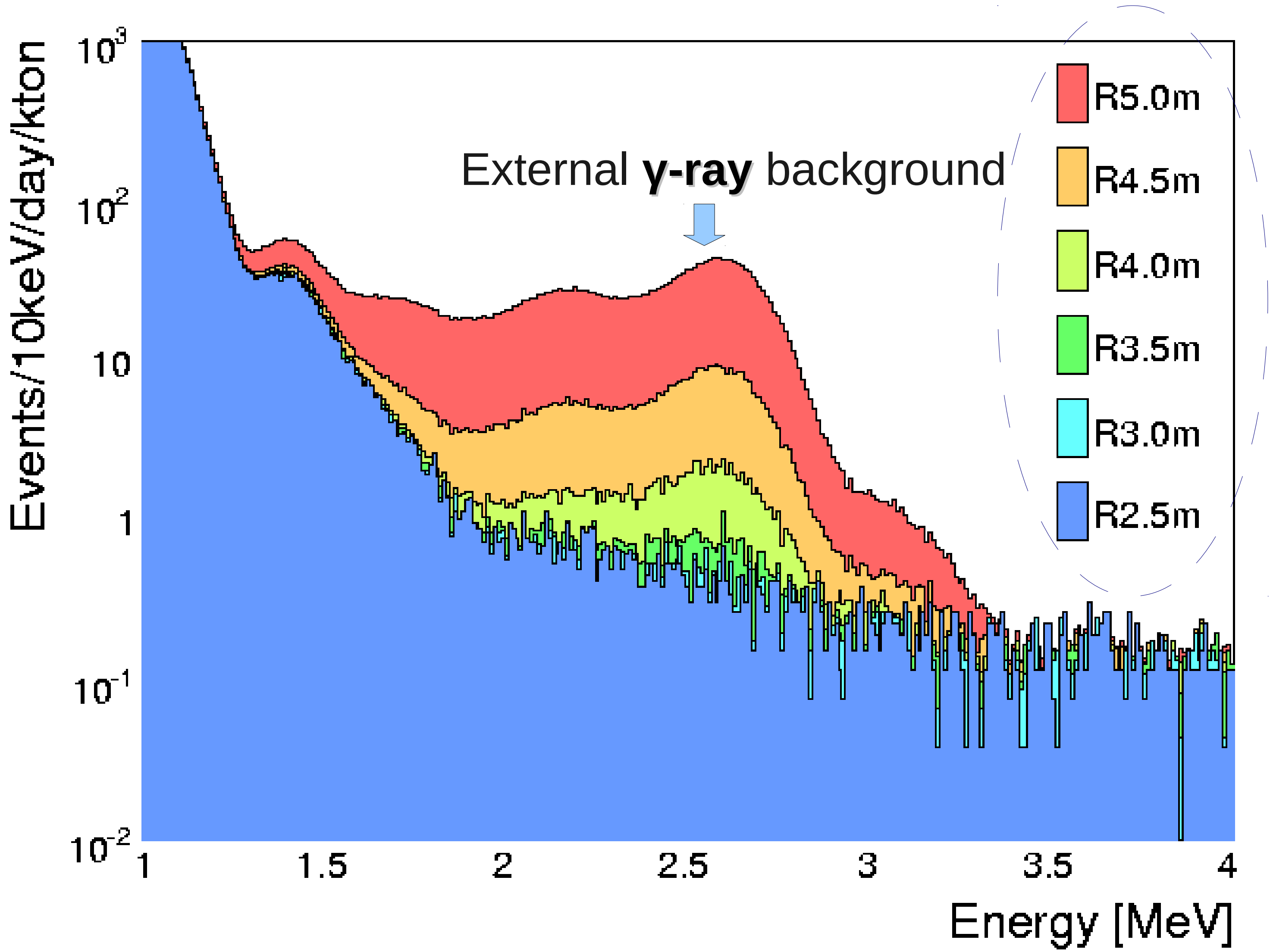
ID Hit Charge





ID: 1879 PMTs 17” + 20”

KamLAND as a clean environment for rare event search



Radial cut

KamLAND provides: an **ultra-pure LS** (**$^{238}U < 3.5 \cdot 10^{-18}$g/g, $^{232}Th < 5.2 \cdot 10^{-17}$g/g**), **1000m** of r**ock overburden.** Moreover, its **central** region is free of external γ-ray background making search for rare **0νββ** or **DM** interaction events possible

The KamLAND-Zen collaboration

(Zero neutrino double beta decay search)

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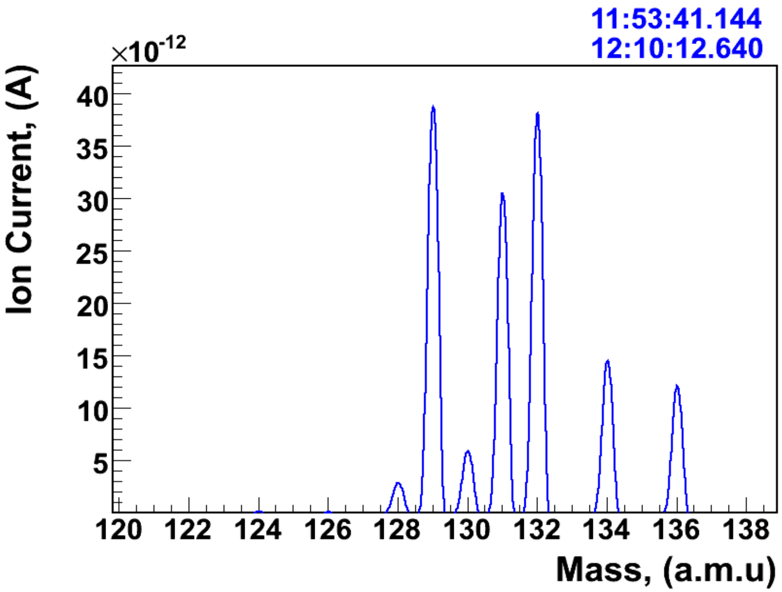
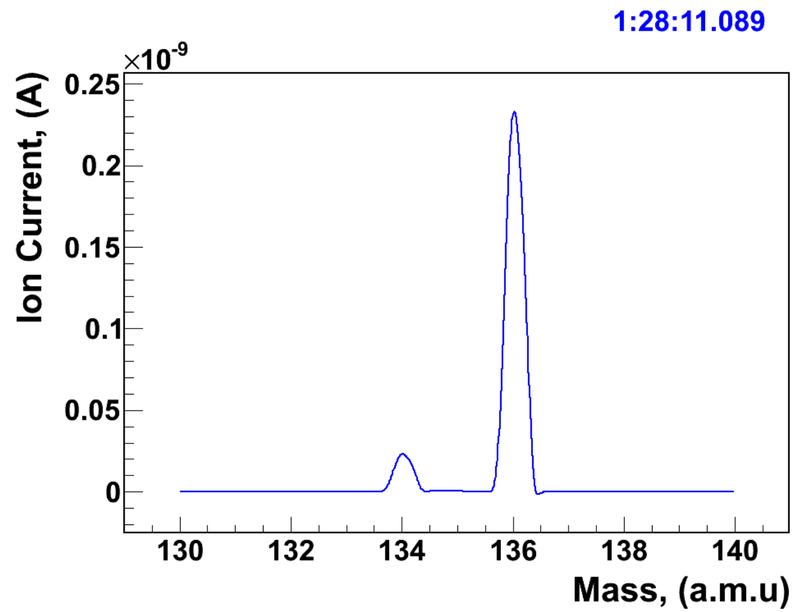
Main criteria for the $0\nu\beta\beta$ isotope selection

We looked for:

- A highest possible **S/N** value taking into acount known background composition (dominated by **^{10}C, ^{208}Tl, ^{11}Be, ^{214}Bi**), the candidate isotope decay energy **Q**, and existence of background from muon spallation products
- A slowest **$2\nu\beta\beta$** decay rate to minimize background due to a relatively low energy resolution of KamLAND
- Availability of isotope, possibility of a **mass production** within a short time period, a **high enrichment** level, and **lowest cost** per kg
- Best **radiopurity** (U, Th, K), and existence of purification methods
- Possibility to produce a **stable liquid scintillator** with a **high light yield**, and **high transparency**

Xenon-136 was selected as best candidate

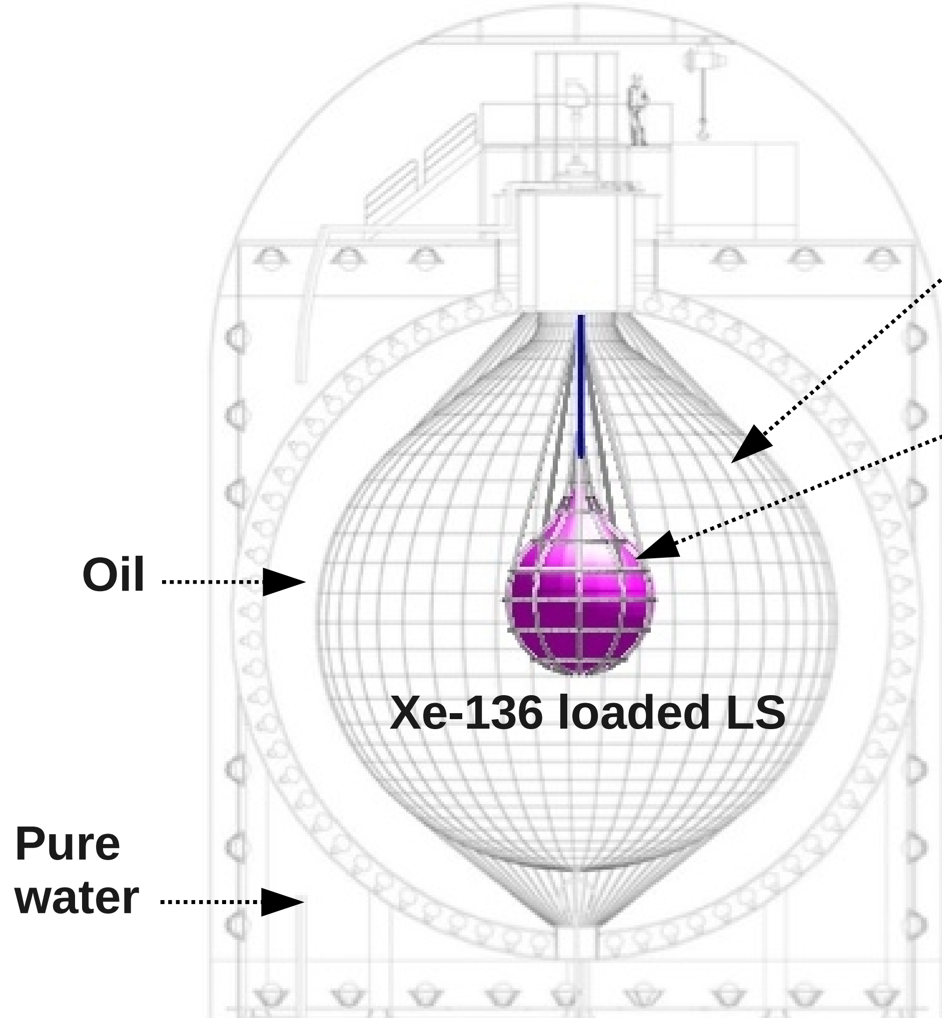




^{136}**Xe** was chousen after comparison to other candidates: ^{130}**Te,** ^{82}**Se,** ^{150}**Nd**

- available facilities for production at a **ton scale in Russia**
- a low cost compared to other enriched isotopes
- a high enrichment level (**91-92%**)
- radioactive impurities removed during enrichment process; additional purification is possible using well established techniques
- soluble in LS (**>3wt%**)
- slowest **2ν2β** background rate: **$T_{1/2}$(2νββ) > 10^{22} years** (at time of selection)
- no substantial light yield, and no transparency reduction in Xe loaded LS

The KamLAND-Zen 0νββ experiment



Old KamLAND scintillator (LS):
Dodecane 80%
Pseudocumene 20%
PPO 1.5g/L

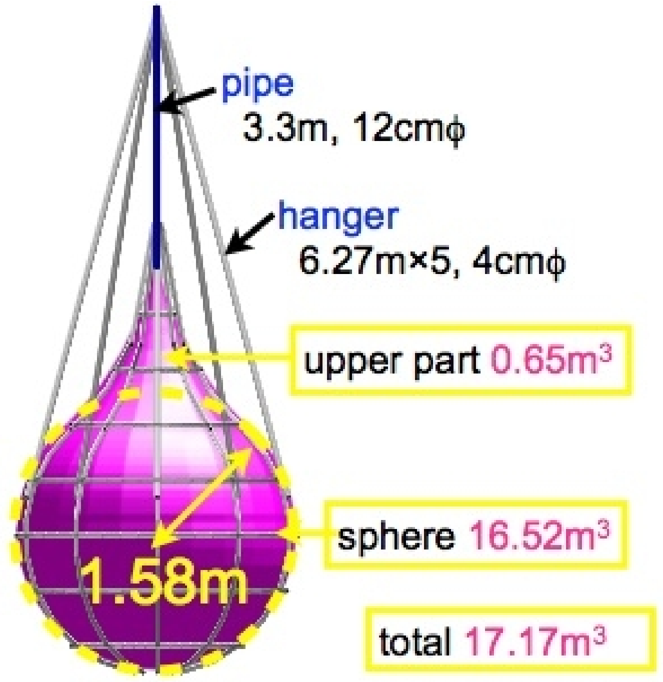
New liquid scintillator :
91% enriched in **Xe-136 (3wt%)**
Decane 80.2%
Pseudocumene 19.8%
PPO 2.7g/L

*Comment: Density and light yield are **equal** to the old KamLAND LS*

Resolution:
Energy 6.8%/√E(MeV)
Spatial 12.5cm/√E(MeV)

- **9m thick shielding** of an ultra-pure LS and buffer oil against external γ-rays
- Possibility to **scale up** the 0νββ experiment by replacing the mini-balloon only (cost and time savings)

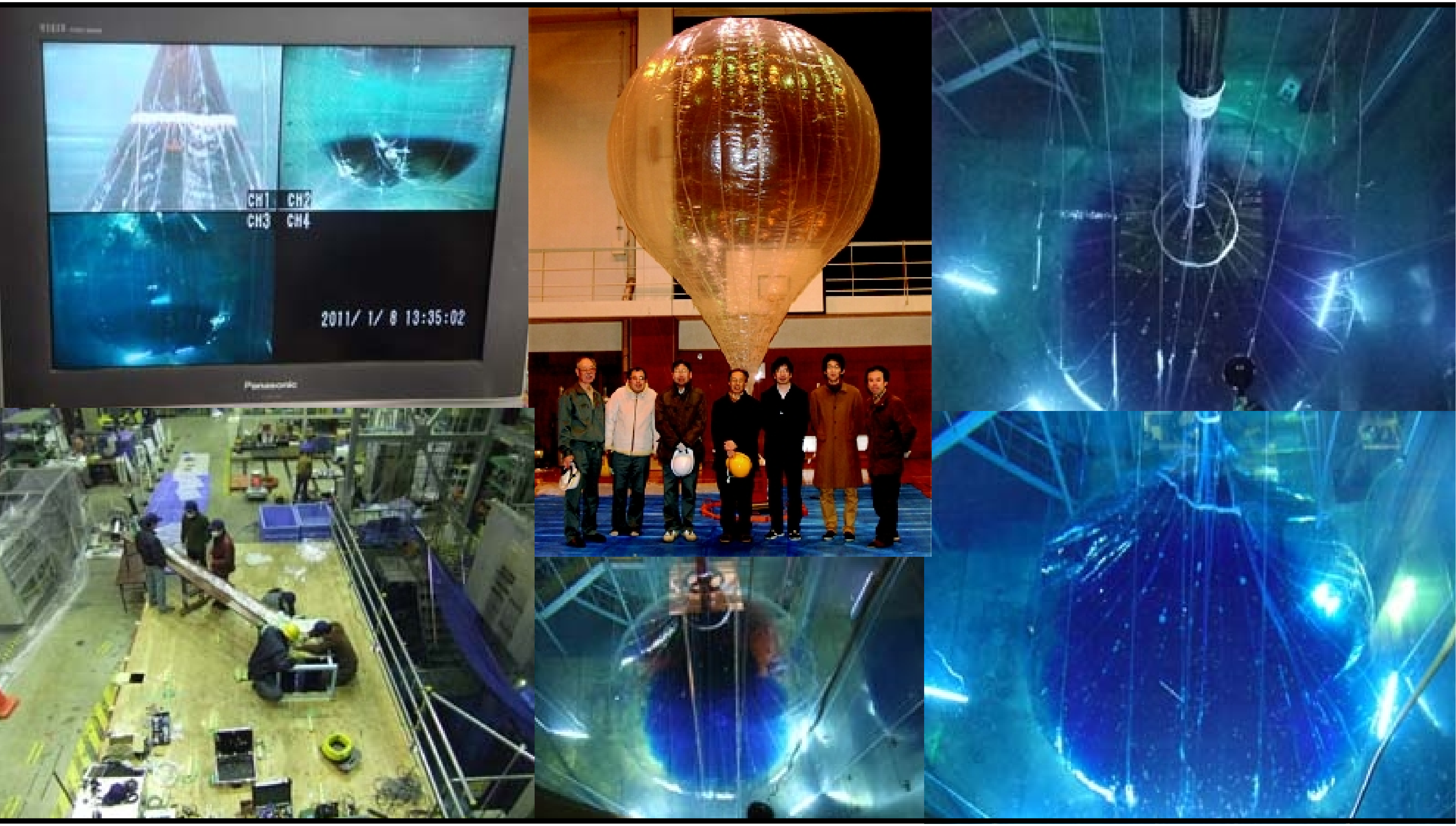
A new mini-balloon for KamLAND-Zen



- A **single layer** Nylon film (Toyobo Co.)
- A **25μm** thick, density 1.14g/cm^3
- Nylon pellets used to make film for the mini-balloon were prepared without additives containing large amounts of U/Th
- The specially made Nylon film contains **^{238}U,^{232}Th~3·10^{-12}g/g, ^{40}K~2.4·10^{-11}g/g**

- During welding of two Nylon films two additional Nylon film strips were added at the boundaries
- Welding was done using an impulse welding machines at **240-250°C** in **0.5-1s** pulses
- The KamLAND-Zen balloon is going to operate at less than **0.1%** density difference relative to the surrounding KamLAND LS

Tests of the mini-balloon prototypes



Balloon development was based on results obtained from several tests of prototypes performed in the air and **underwater** in a large pool. The one of the balloon prototypes was successfully inflated in the the pool using colored water of **0.04%** higher density.

The mini-balloon construction at an ultra-clean facility (Tohoku university)

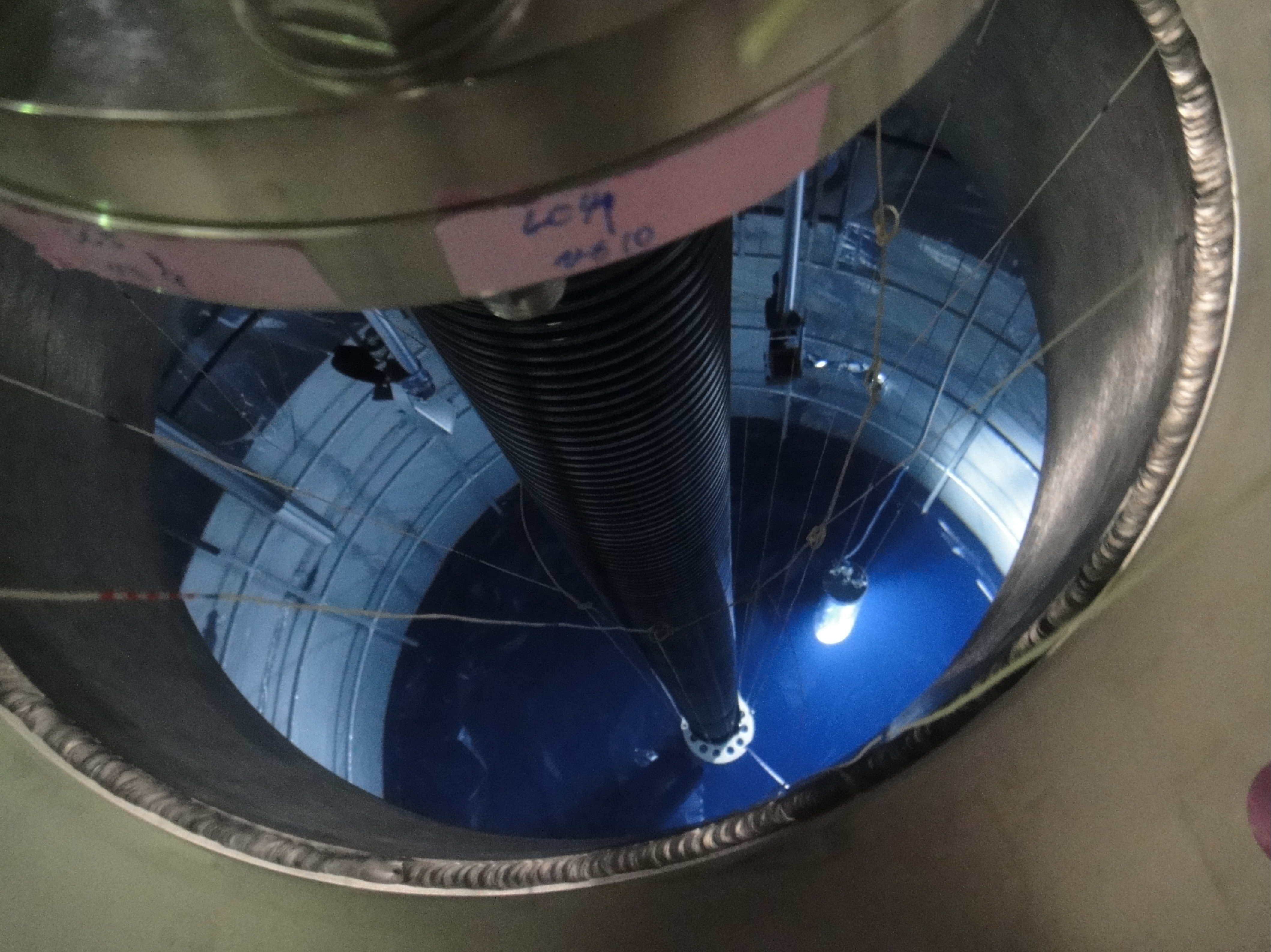
Nylon welding

Packing

Package sealed; N_2 gas purged

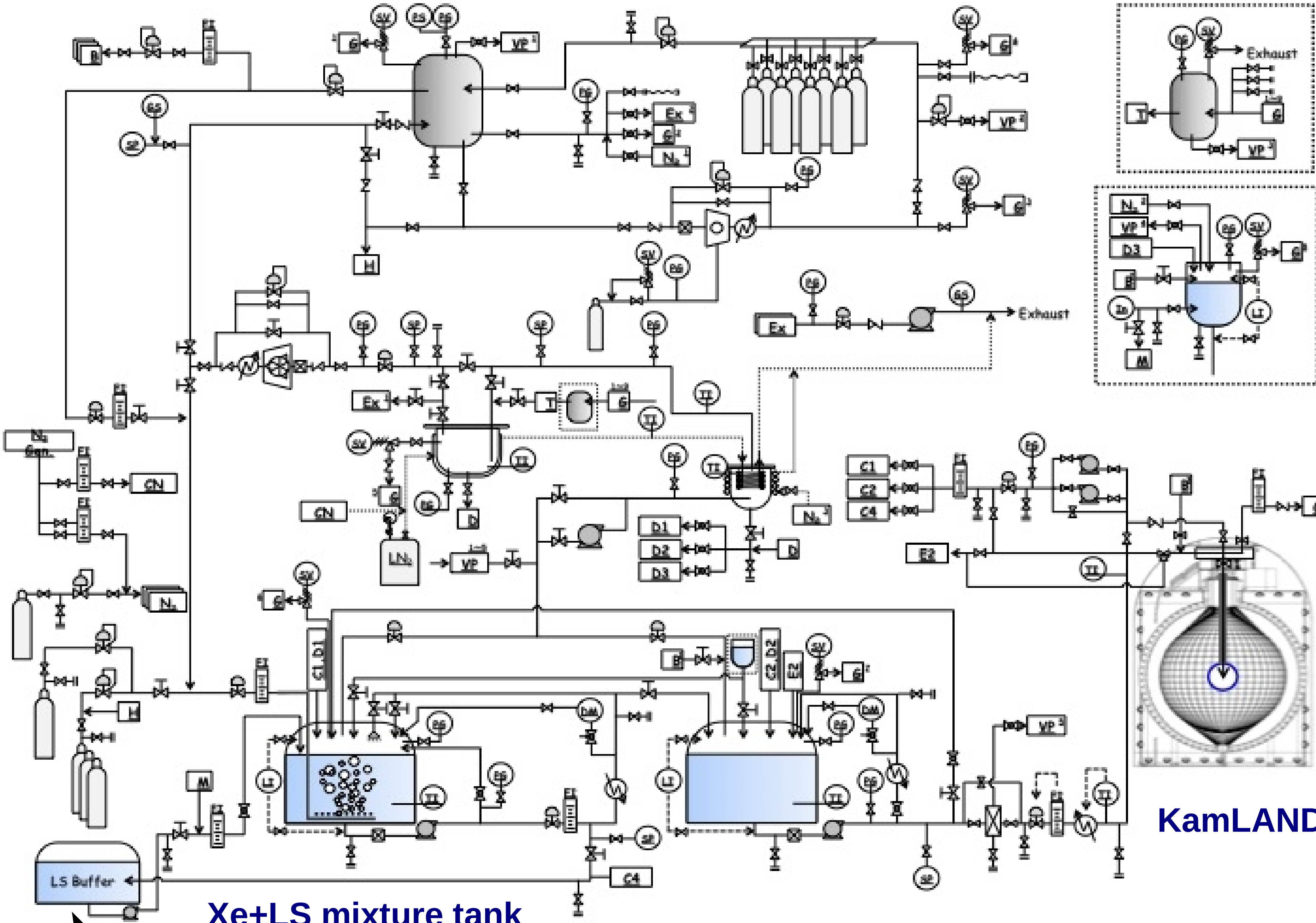
Before the mini-balloon installation: setting LED, cameras

The mini-balloon installation



The mini-balloon installation completed

Xenon gas storage



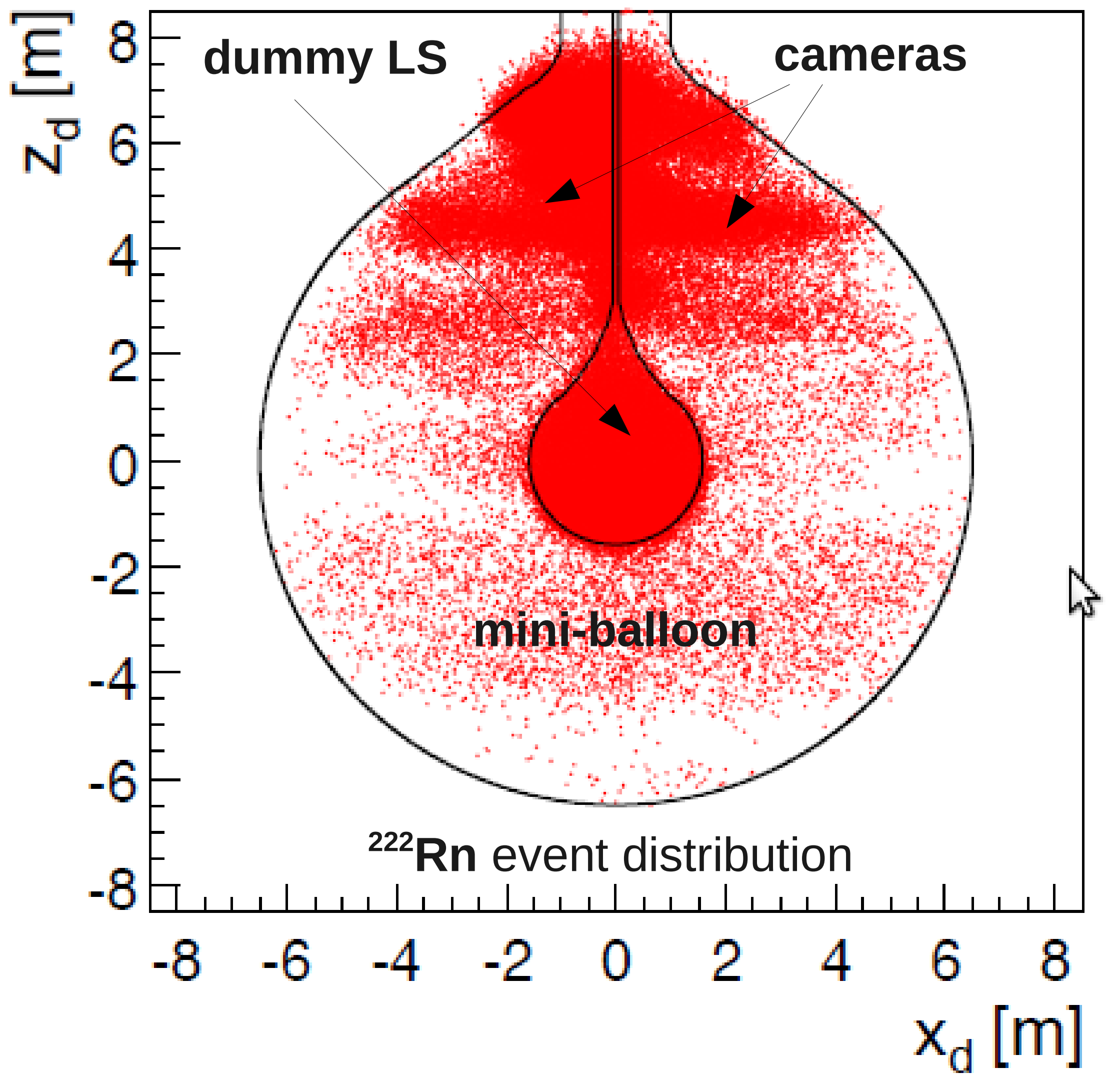
Xe+LS mixture tank

KamLAND

Purified LS
(by water extraction + distillation)

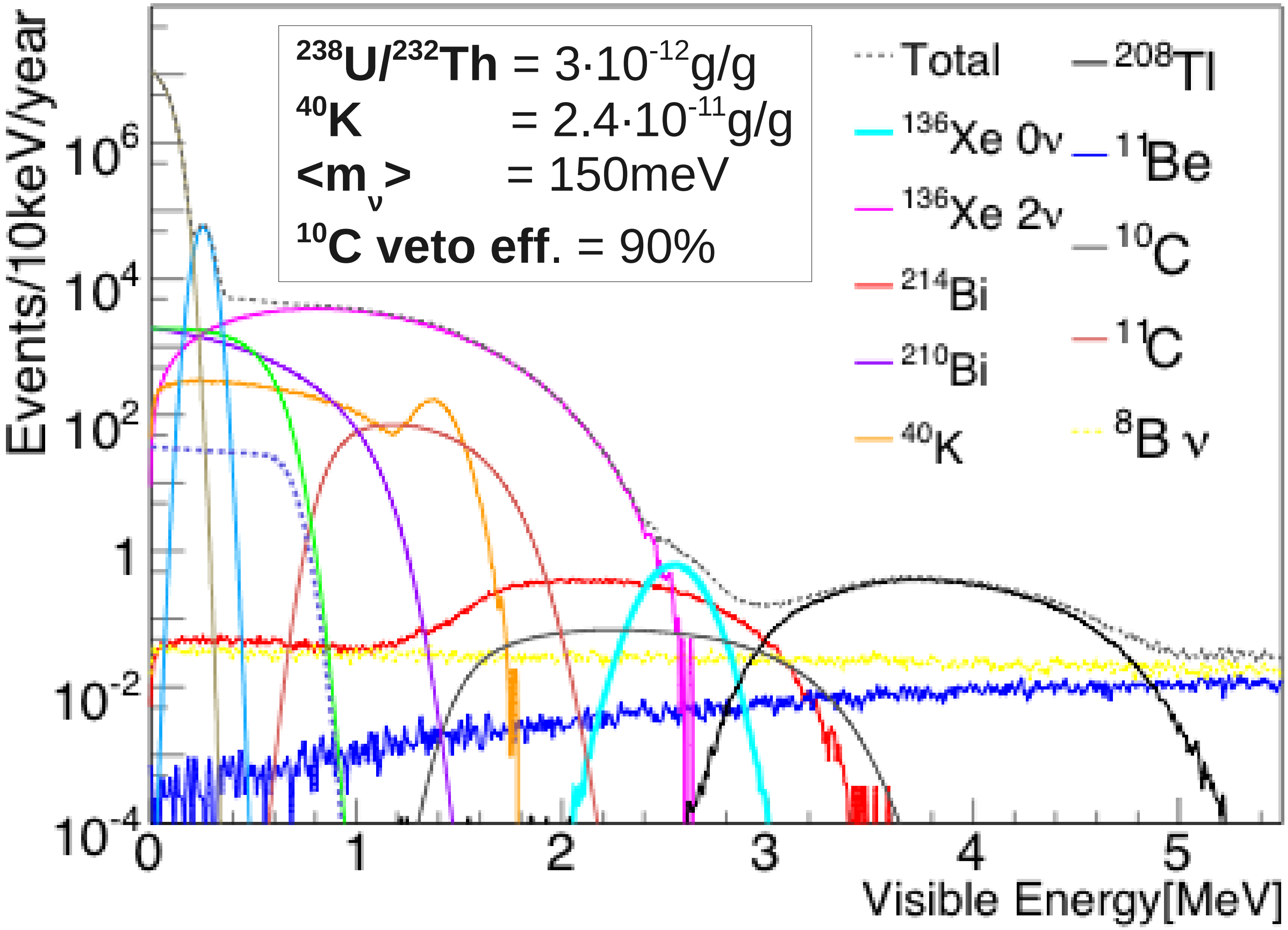
(Schematic view of the Xenon handling system)

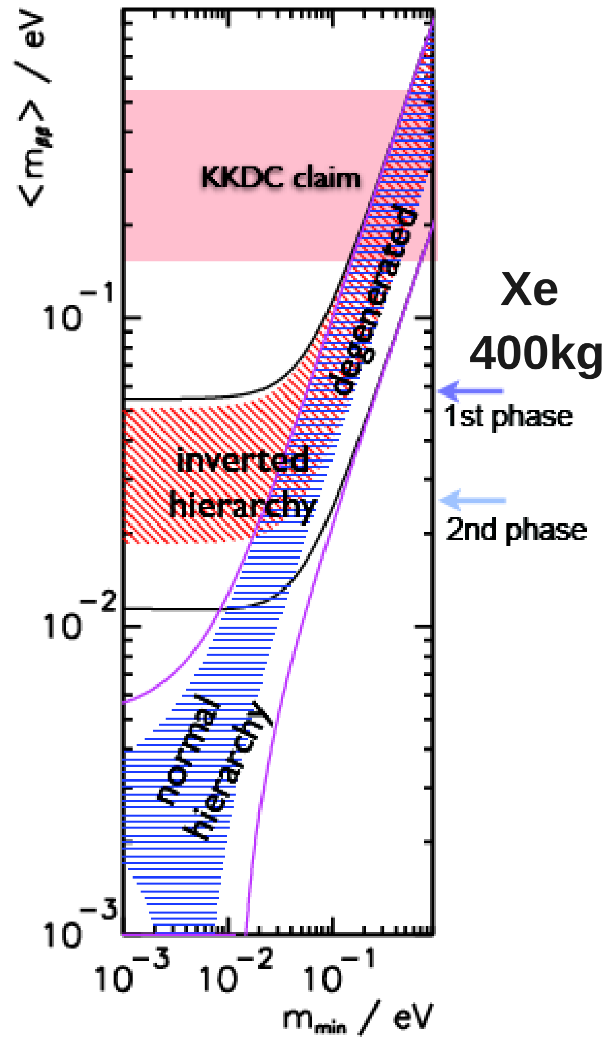
Next step towards the KamLAND-Zen operation



- The **mini-balloon** installation into the KamLAND detector completed
- **Next** is replacement of the dummy LS by a (heavier) **Xenon loaded LS**

The expected 0νββ signal vs background

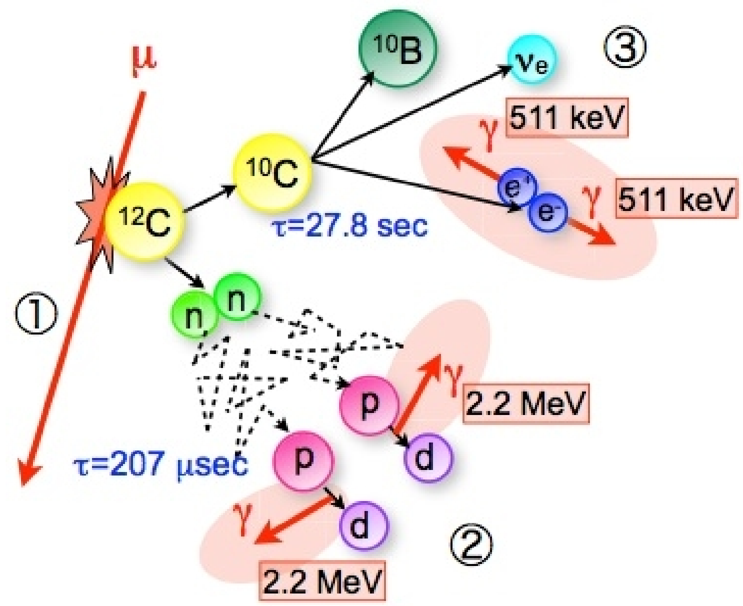


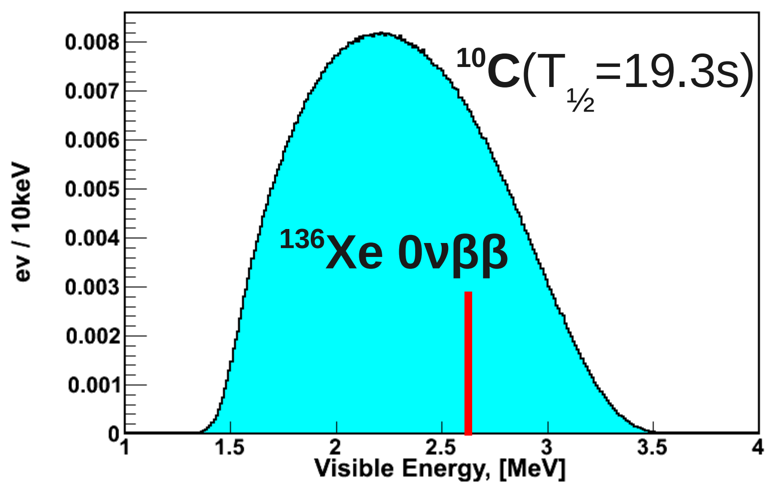


^{136}Xe 2ν	^{208}Tl	^{214}Bi	^{10}C	^{11}Be	^{8}B	Total	^{136}Xe 0ν
8.55 ±0.67	6.97×10^{-3} $\pm0.93\times10^{-3}$	8.55 ±0.06	1.85 ±0.01	0.15 ±0.01	0.93 ±0.02	19.53 ±0.67	14.59 ±0.02

Summary: expected signal and background (events/year)

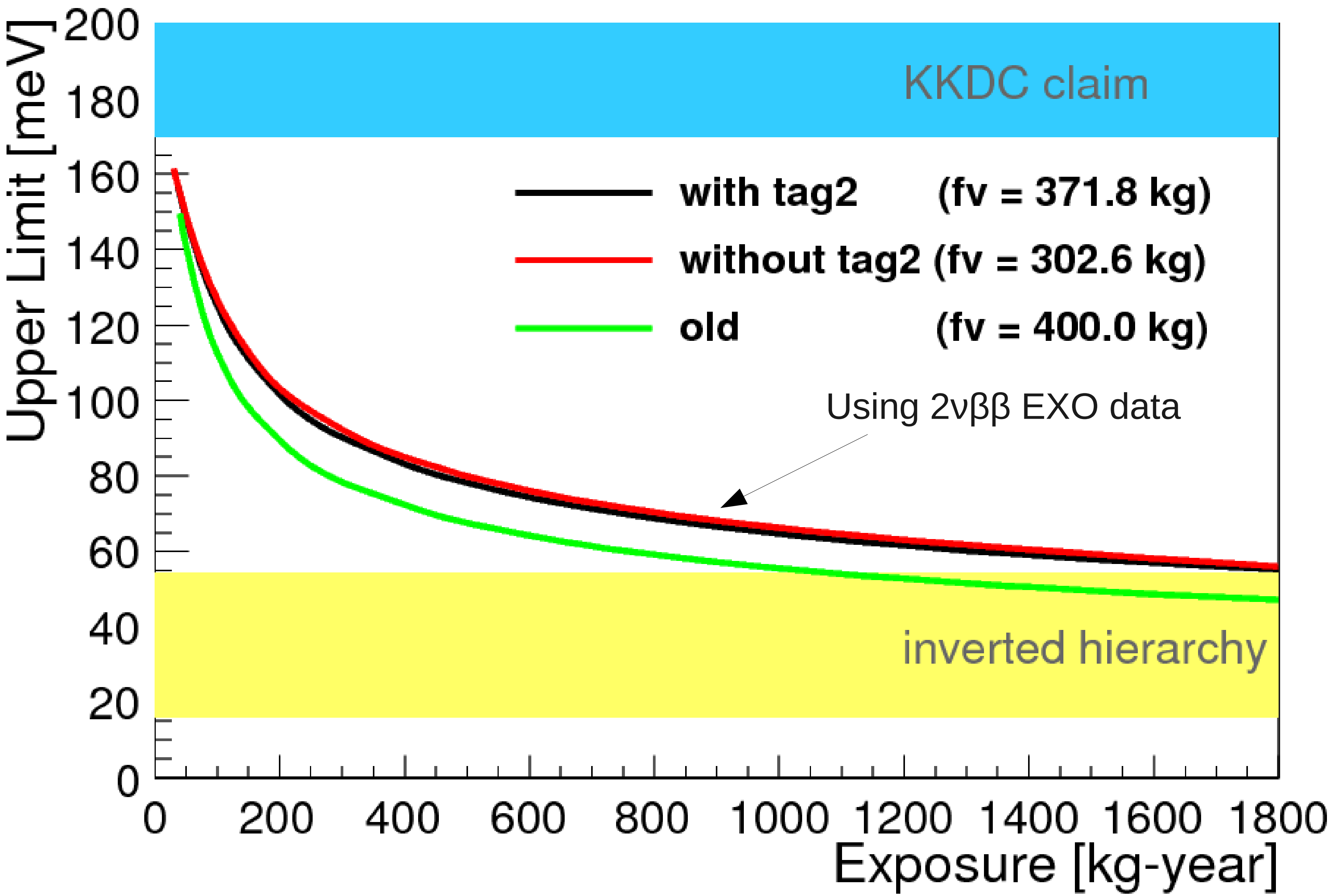
The C-10 background reduction





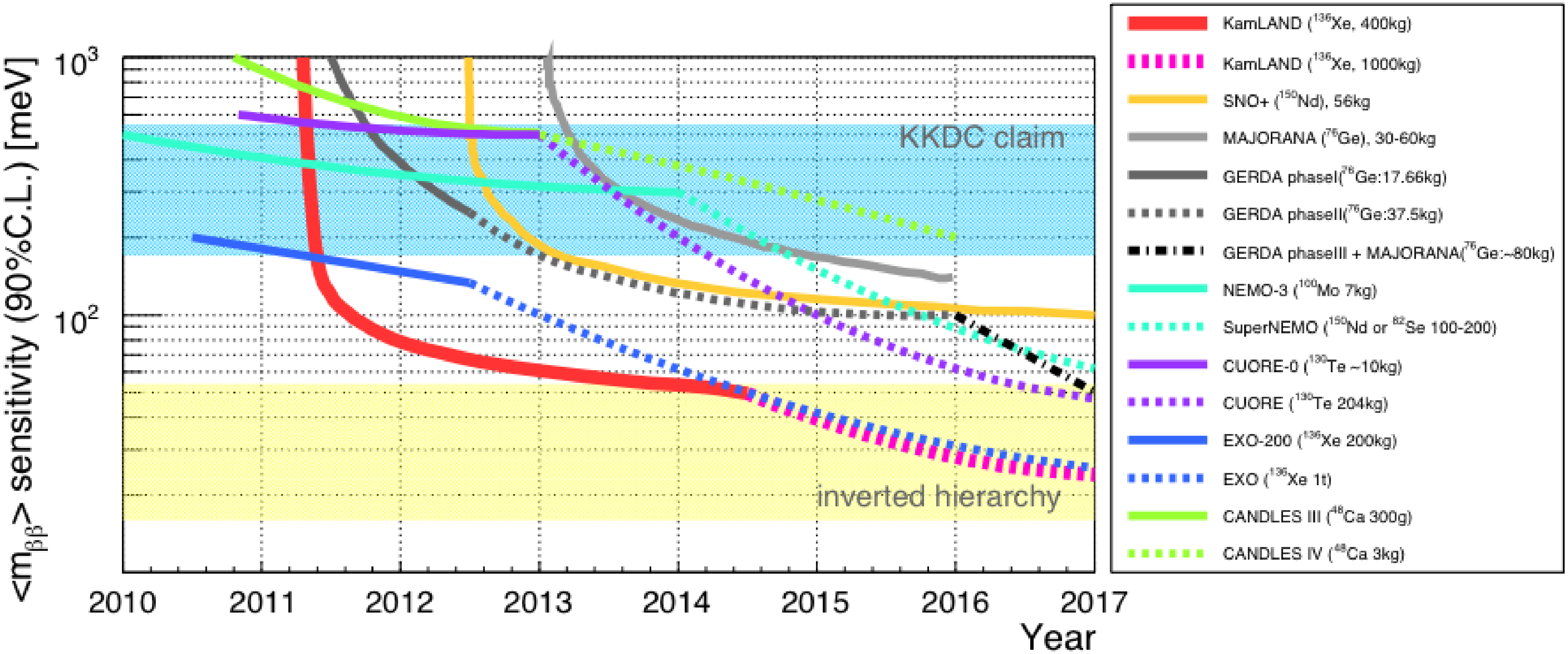
The ^{12}C + μ → ^{10}C + X production rate is **21.1 events / kton / day.** A new dead-time free electronics (MOGURA) allows to detect **2.22MeV γ-rays** from **n+p** after bright **μ** signals, and thus **veto** (with a **95%** efficiency) detector regions where **^{10}C nuclei** were produced.

Expected sensitivity during the phase 1 (400kg)



90% C.L. Upper limit on effective neutrino mass vs exposure

Summary



- KamLAND is being modified into KamLAND-Zen to search for new physics
- **Phase 1**: **389kg** of Xenon **91%** enriched in **Xenon-136** is going to be used.
  Goal: to cover the effective neutrino mass range corresponding to the **KKDC** claim and **degenerated hierarchy** region (2 years of data taking)
- **Phase 2**: **1000kg** of enriched Xenon-136 with or without the detector upgrade to improve the energy resolution are being considered
  Goal: to cover most of the **inverted hierarchy** region