Perspectives for 2β0ν Search at the KamLAND

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MEDEX’11: June, Prague

(On behalf of the KamLAND-Zen collaboration)

KamLAND-ZeN collab.

(Subset of the Original KamLAND team)

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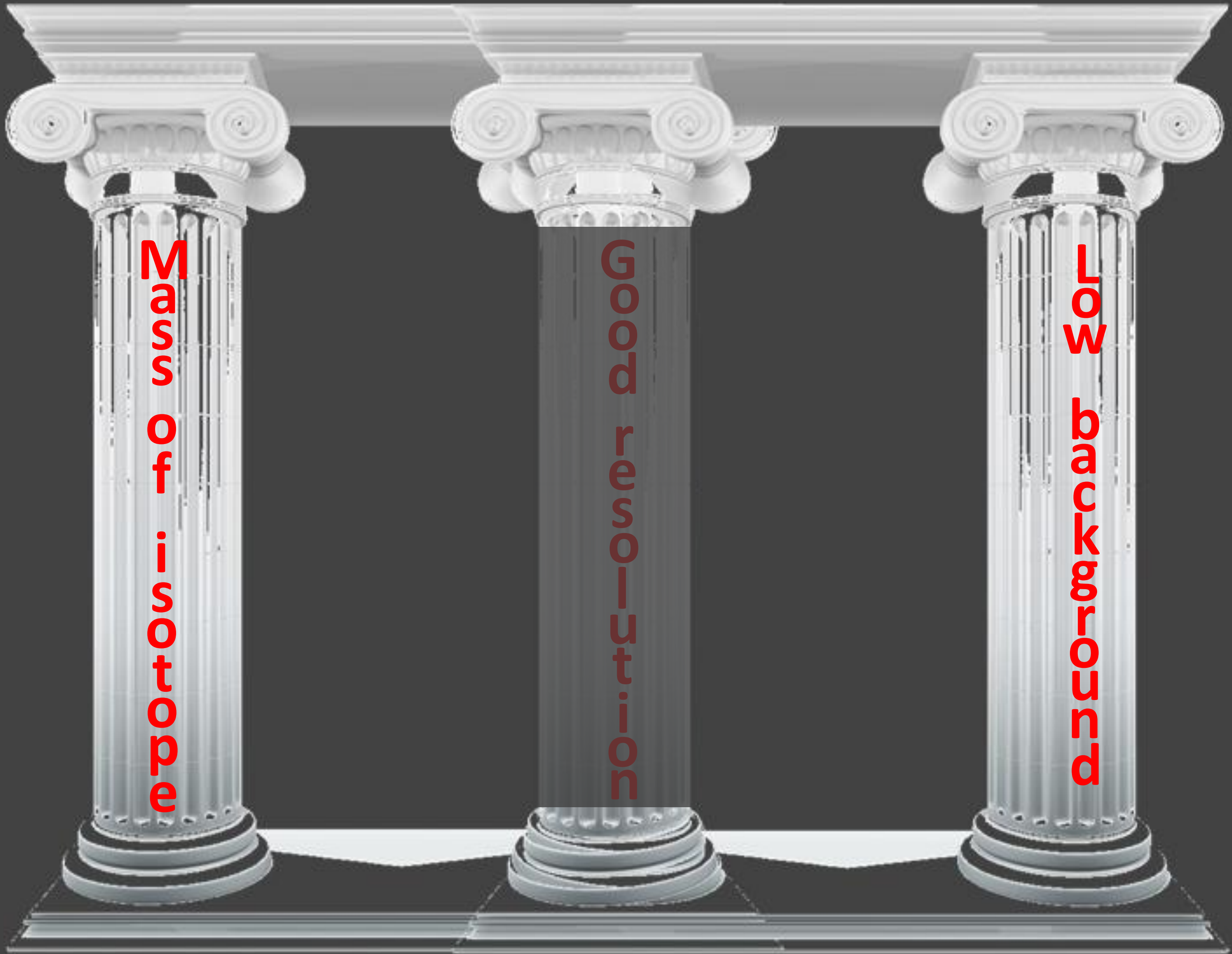
Three pillars of 2β0ν (Exp.)

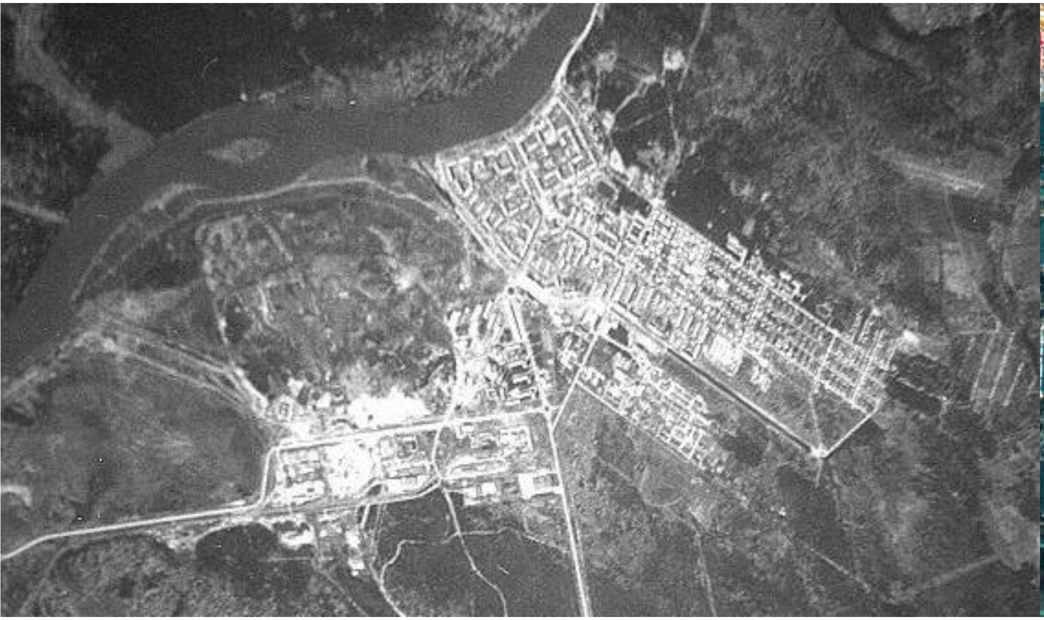


How to Afford a Large Mass of a Isotope

I "non expensive" enrichment:

Ia Use existing operational facility

Ib Use gaseous Isotope (5-7 time less expensive than solids)



II. Use existing Infrastructure for the detection

- Non expensive modifications to do search for $2\beta0\nu$
- Detector does exist and well understood

Existing Large Neutrino detectors are a good match

2β decay Isotopes

Isotope	Q value, keV	$T_{1/2}$ 2β2ν, Y.	Mass of Isotope in Kg to have one decay per year for $<m_{\nu\beta\beta}>$ =0.1eV	Natural Abundance
^{48}Ca	4271	$4.4 \cdot 10^{19}$	55÷80	0.0019
^{76}Ge	2039	$1.5 \cdot 10^{21}$	35÷60	0.078
^{82}Se	2995	$9.2 \cdot 10^{19}$	18÷30	0.092
^{96}Zr	3351	$2.3 \cdot 10^{19}$	15÷20	0.028
^{100}Mo	3034	$7.1 \cdot 10^{18}$	13÷21	0.096
^{116}Cd	2805	$2.8 \cdot 10^{19}$	14÷24	0.075
^{128}Te	867	$1.9 \cdot 10^{24}$	300÷450	0.317
^{130}Te	2529	$6.8 \cdot 10^{20}$	15÷23	0.345
^{136}Xe	2476	$>10^{22}$	34÷50	0.089
^{150}Nd	3367	$8.2 \cdot 10^{18}$	14÷41	0.056

O.Civitarese and J.Suhonen 2009 *J. Phys.: Conf. Ser.* 173 012012

^{48}Ca M.Horoi, S.Stoica arXiv:0911/3807 [nucl-th]

^{150}Nd F. Simkovic, AIP Conf. Proc. 942, 77

Element → Xenon

"Noble" gas

Dissolvable in Liquid Scintillator

Density 5.894 g/l

Melting point -111.7 ^{o}C

Boiling point -108.2 ^{o}C

World production ~30÷40 t/y

Applications: Illumination, Anesthesia, Particle detectors, Ion thrusters

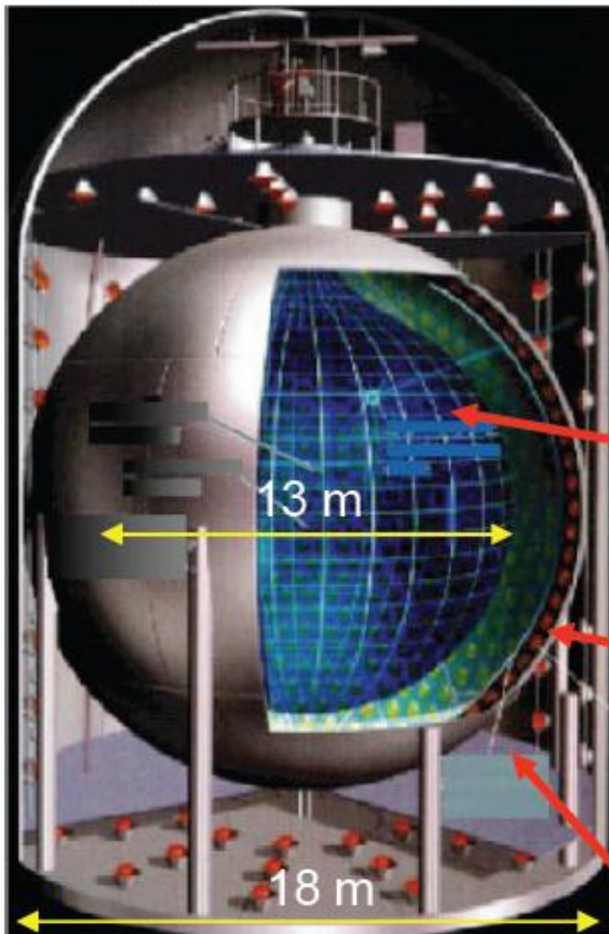
^{136}Xe

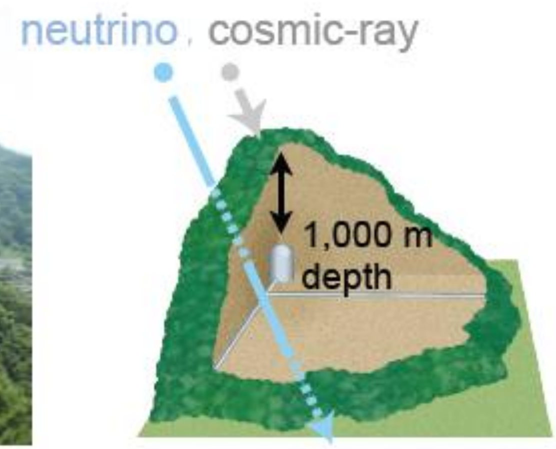
Natural Abundance:	8.9%
$Q_{2\beta}$ value:	2476 keV
$T_{1/2}$ $2\beta2\nu$	$>10^{22}$ y.
$T_{1/2}$ $2\beta0\nu$ for 50 meV	$\sim3.0\div4.4\cdot10^{26}$ y.

Detector →KamLAND

Kamioka Liquid Scintillator Anti-Neutrino Detector

operated since 2002





1,000 ton Liquid Scintillator

Dodecane (80%) Pseudocumene (20%) PPO (1.5 g/l)

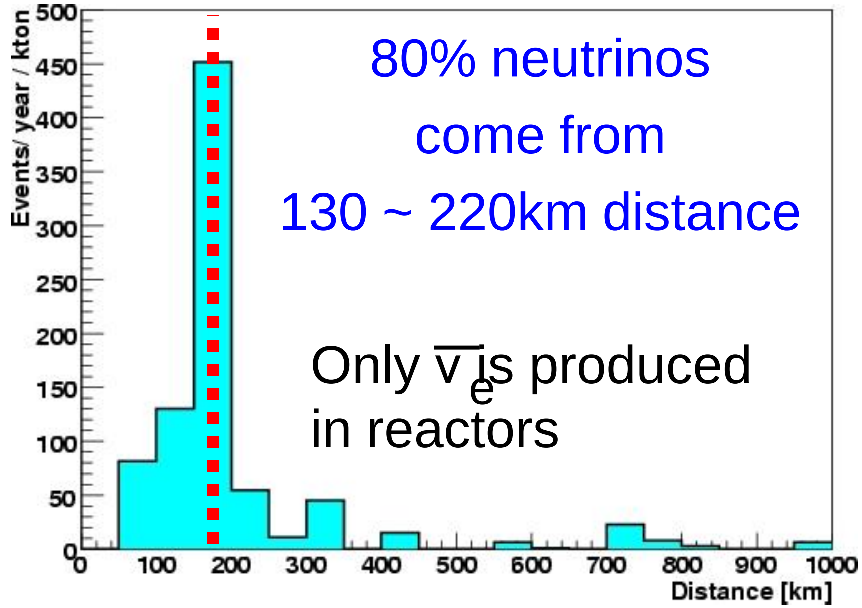
1,325 17 inch + 554 20 inch PMTs

commissioned in February, 2003

photocathode coverage : 22% → 34%

Water Cherenkov Outer Detector

KamLAND and Reactors



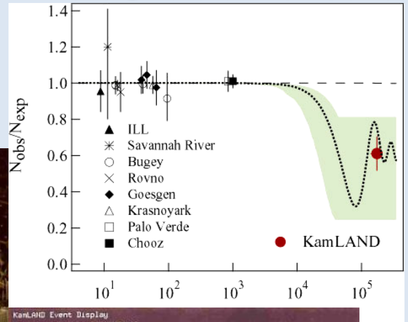
Effective distance ~180km

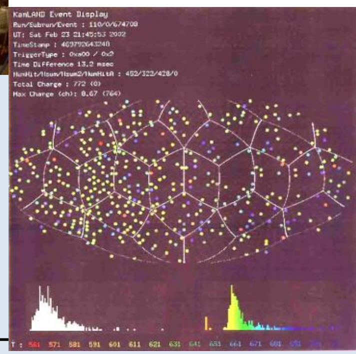
Reactor neutrino flux ~ $6 \cdot 10^6$ /cm^2/sec

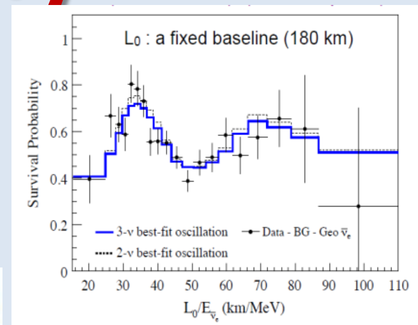
- **Japan reactors 94~97%**
- **Korea reactors 3 ~ 5%**
- **world reactors ~ 0.5%**

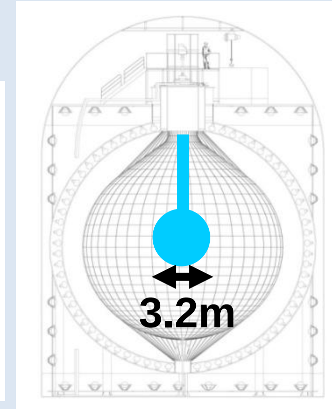
Main focus was to search for neutrino oscillations in a long baseline experiment with nuclear power plants as the source

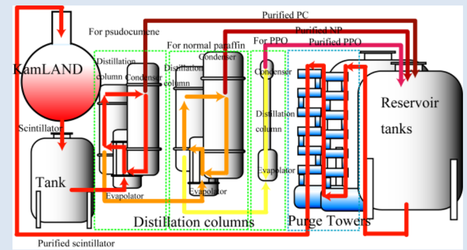
KamLAND History











1998 2000 2002 2004 2006 2008 2010 2012

Dismantling of old Kamioka detector

KamLAND proposal 1999.

To search for $\beta\beta0\nu$-decay with the KamLAND detector we would need to dissolve a large quantity of a $\beta\beta$ unstable isotope in the liquid scintillator. This will allow a calorimetric measurement of the sum energy of the emitted electrons as proposed in [115]. Lik R.S. Raghavan, Phys. Rev. Lett. 72 (1994) 1411

From all double beta emitters which have been considered for this estimate, ^{136}Xe is the most promising candidate. The noble gas Xe dissolves to up to 2% by weight in

New purification system

Best limit on Extraterrestrial $\overline{\nu}_e$

Double Beta Decay

KamLAND-Zen

Mini balloon

Radius:	1.58m
Material:	nylon-6
Thickness	25µm
Density	1.14 g/cm3
Weight	900g

Xe loaded liquid scintillator

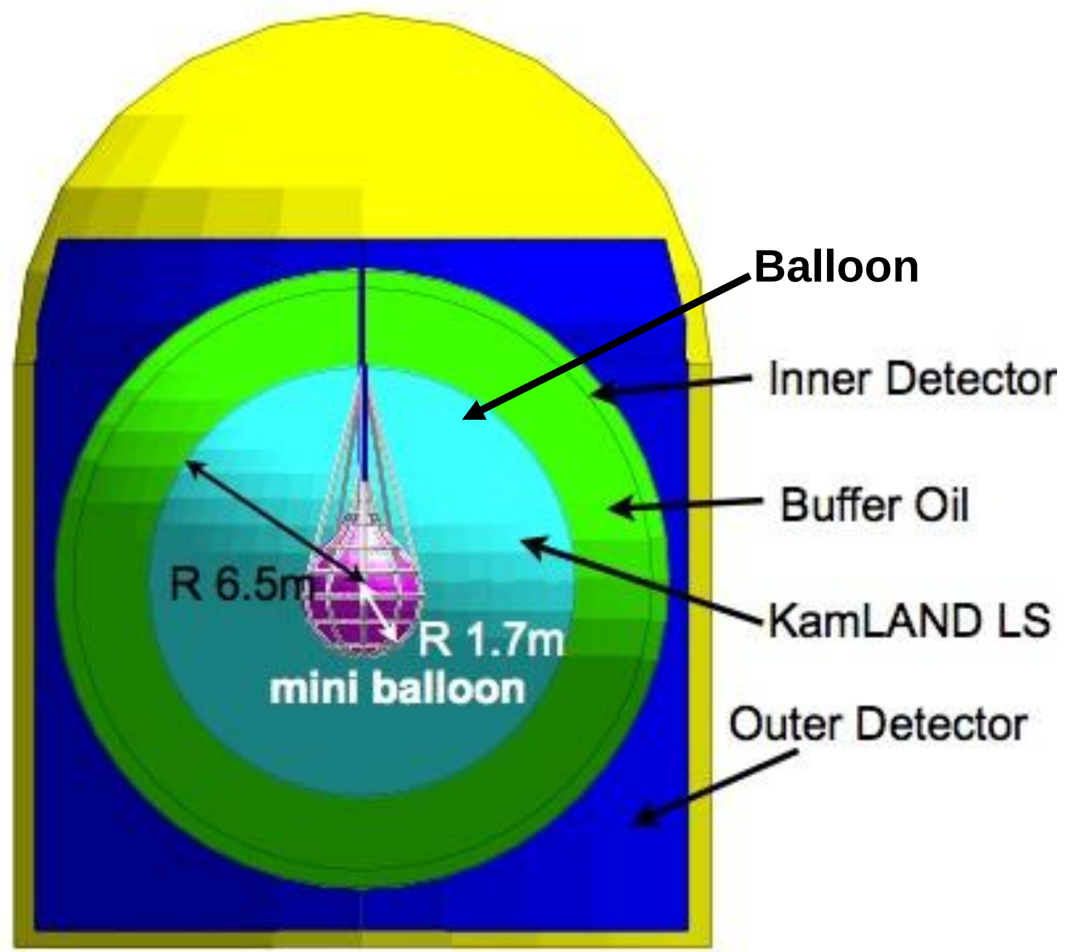
91.7% enriched ^{136}Xe 400kg (3.0wt%)

Composition ratio

Decane	82.3 %
Pseudocumene	17.7 %
PPO	2.7g/l

Density : same as for the KamLAND liquid scintillator (0.777 g/cm^3)

Light yield : same as for the KamLAND liquid scintillator



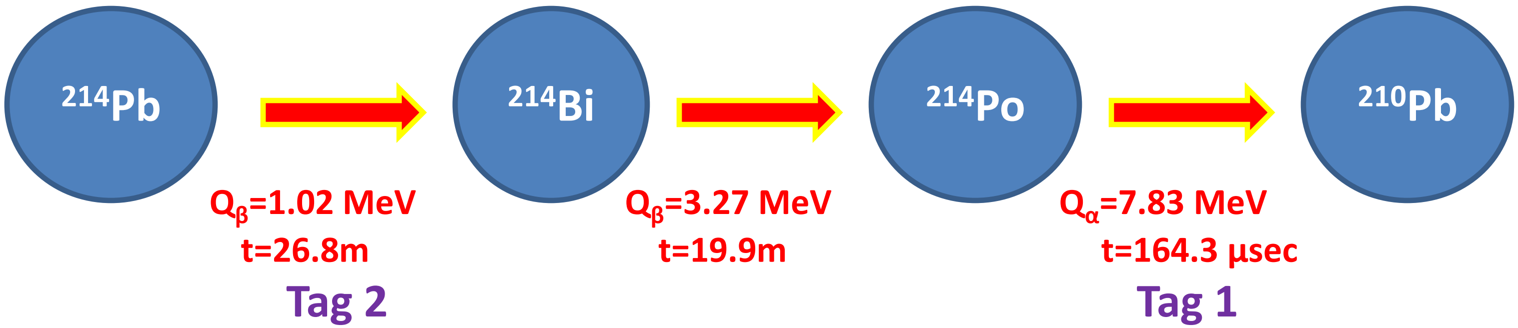
Energy Resolution: 6.8%/ $\sqrt{E(\mathrm{MeV})}$

Vertex Resolution: 12.5cm/$\sqrt{E(\mathrm{MeV})}$

Internal Backgrounds

^{208}Tl in scintillator or balloon is not a big problem because energy is higher than 2β0ν window

^{214}Bi in scintillator or Balloon is a problem because its spectrum is crossing 2β2ν window. Need very low U contamination and efficient tagging.

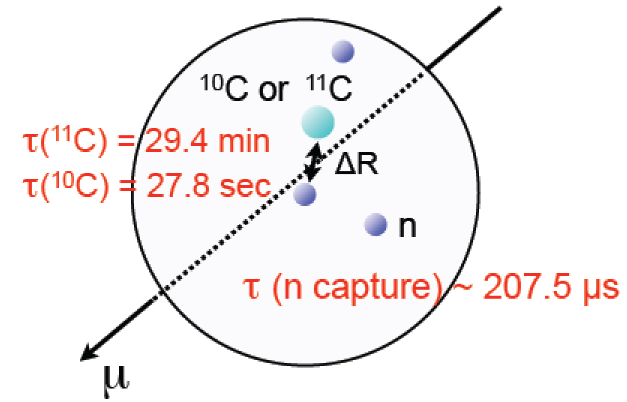


Second Tag is working well in scintillator. However if ^{214}Bi is in the balloon alphas could stay there. → As result there are strict requirements on U radioactivity in the balloon of $<10^{-12}$ g/g, and on the balloon thickness <25 μm

2β2ν tail could be a problem. Reasonably good energy resolution is required

External Backgrounds

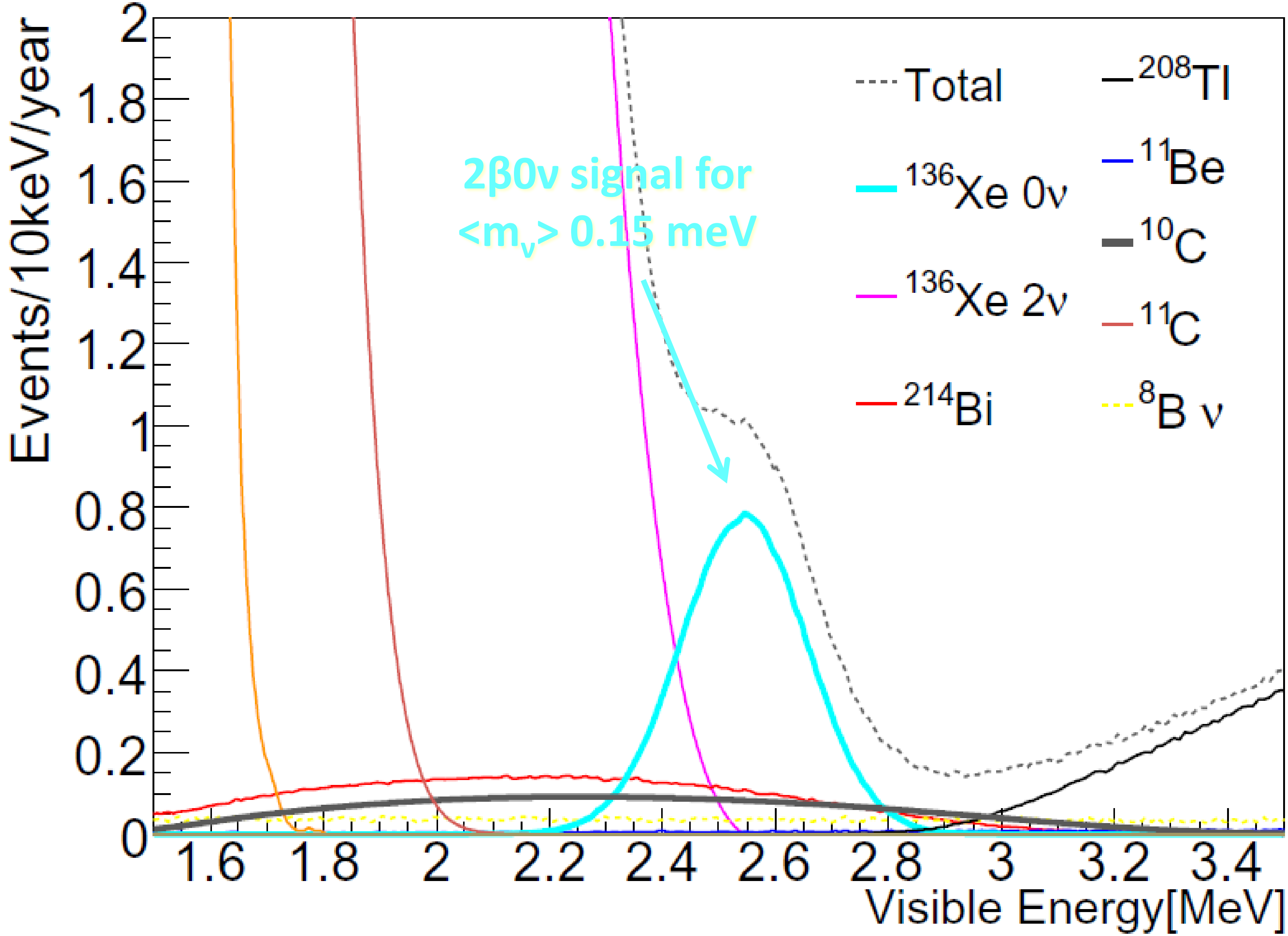
^{10}C Generated in Scintillator by cosmic rays at the KamLAND depth with the rate of 21.1±1.8 atoms kton/day. They can be tagged by neutrons captures.



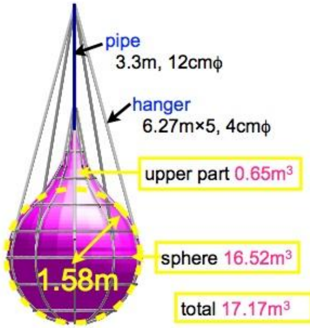
According to simulations such a tagging will let us to reduce this background by factor of ~ 10.

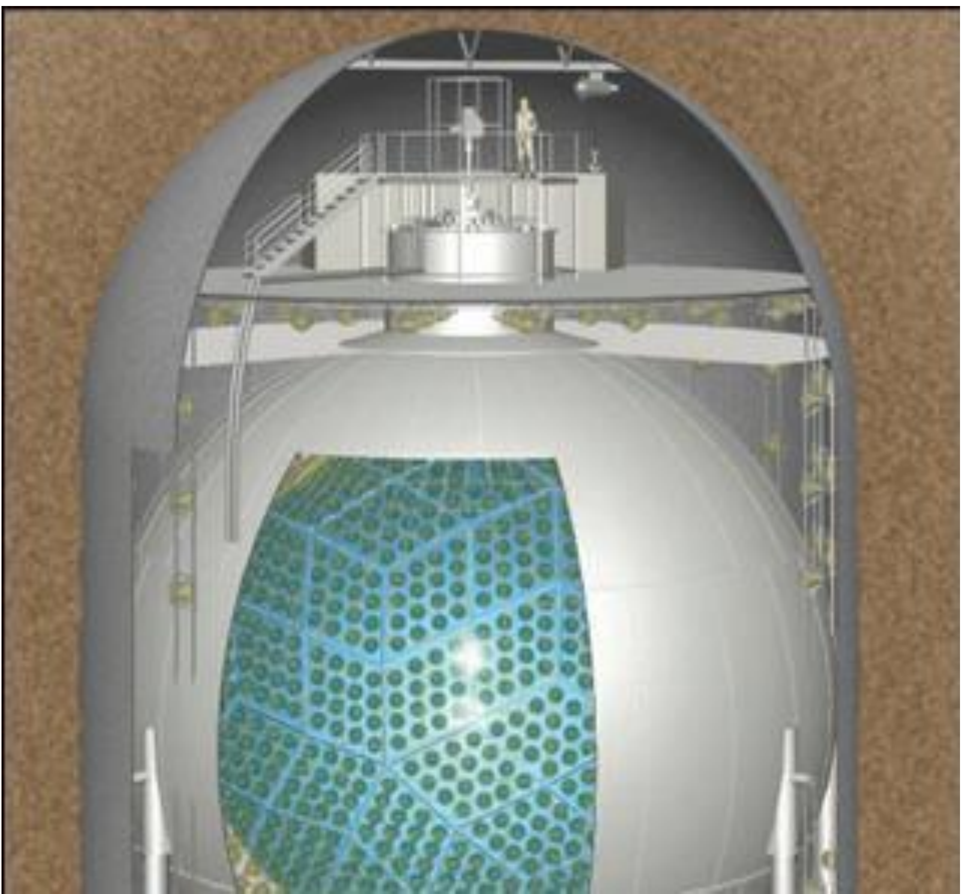
As result it will be comparable to the Irreducible background from ^{8}B solar neutrinos (~0.03 /10kev/Y) at the R.O.I.

Expected Backgrounds

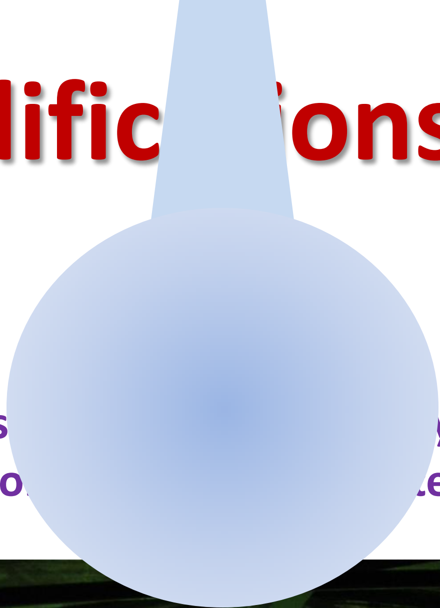


KamLAND Deck Modific[illegible]ions





Need s[illegible]y Mini
balloo[illegible]ector



Mini Balloon Details

Assembly/Deployment

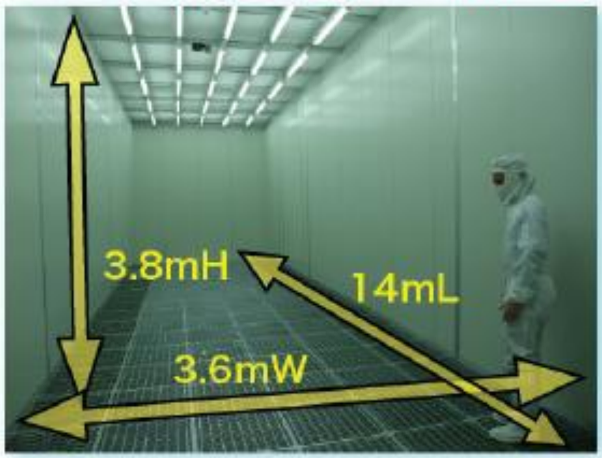
- Weld Balloon together, test it for a leaks.
- Fold it and wrap inside protective layer (Cocoon)
- Move to the detector site.
- Remove transportation protective layer in a clean environment
- Lower its bottom while it is folded via chimney.
- Filled it with small amount (~100 l.) of scintillator with density higher than that of KamLAND scintillator.
- Deploy it all the way, remove protective layer and straps.
- Expand it using regular liquid scintillator
- Replace regular scintillator with Xe loaded scintillator

Test deployment of Prototype

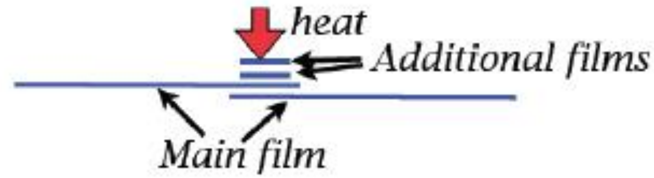
Mini Balloon Status

Super clean room is ready !
(at Nishizawa center of Tohoku Univ.)

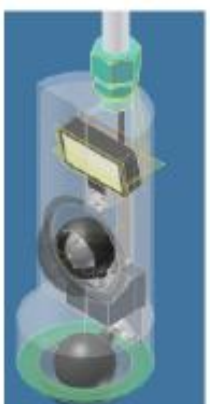
Class 1 (=1 particle(>0.1μm) /feet^3)



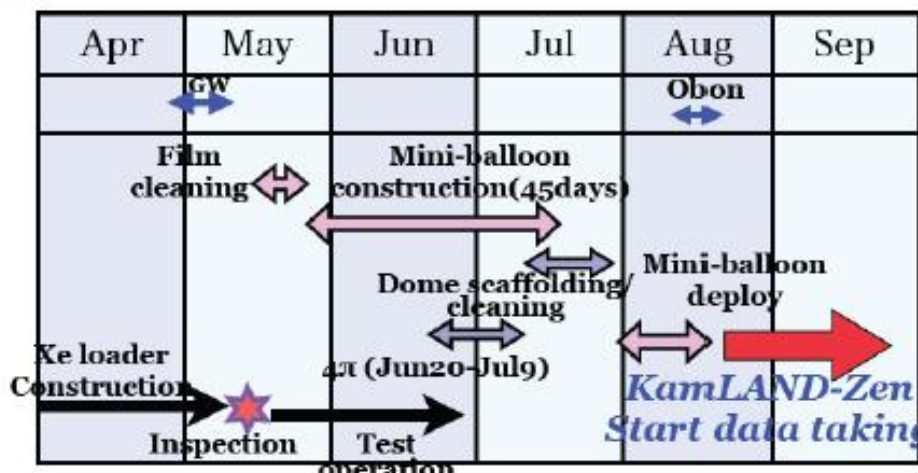
Welding method and conditions has been established.



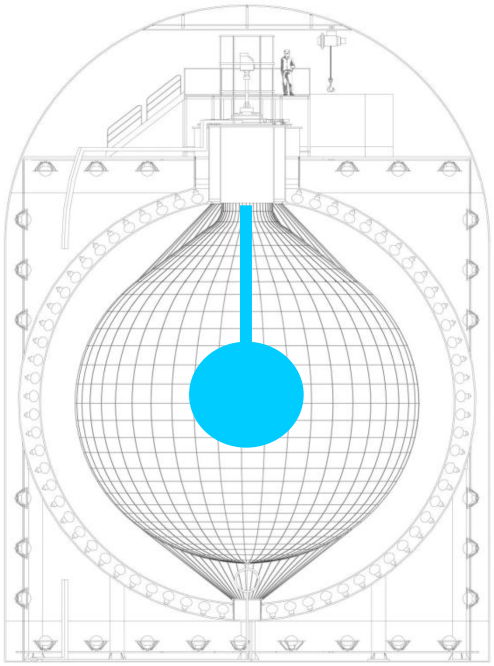
Final checks and preparation of the balloon construction and deployment are ongoing.



Designing the monitor cameras and lights in the deployment are finished and will be ordered soon.

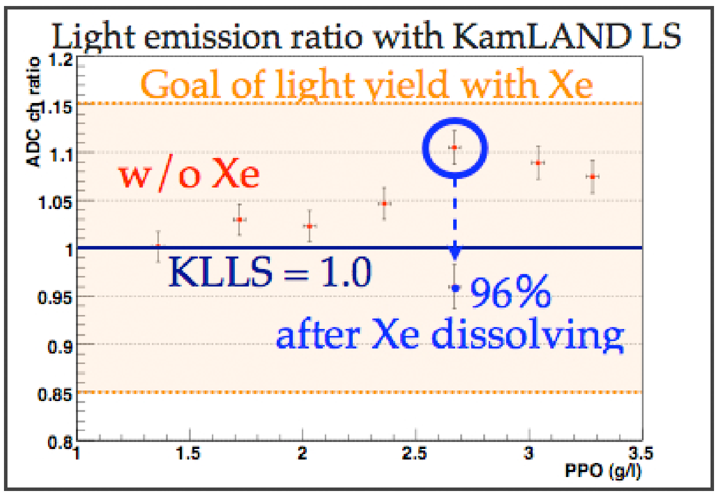


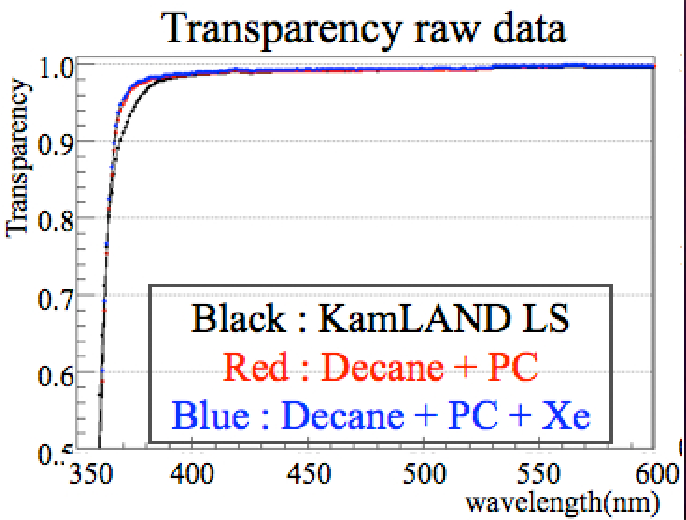
Scintillator

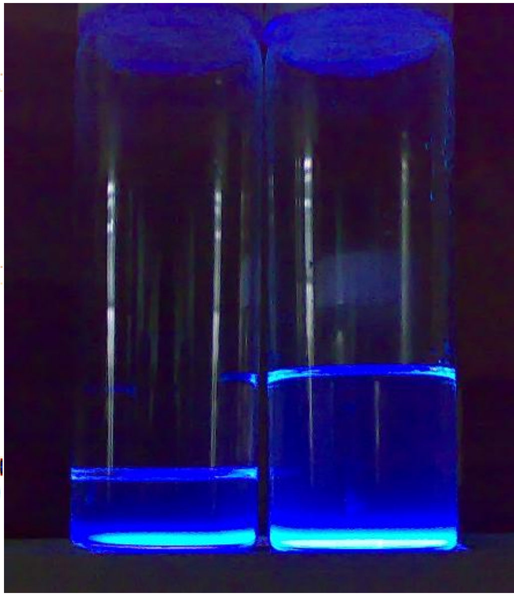


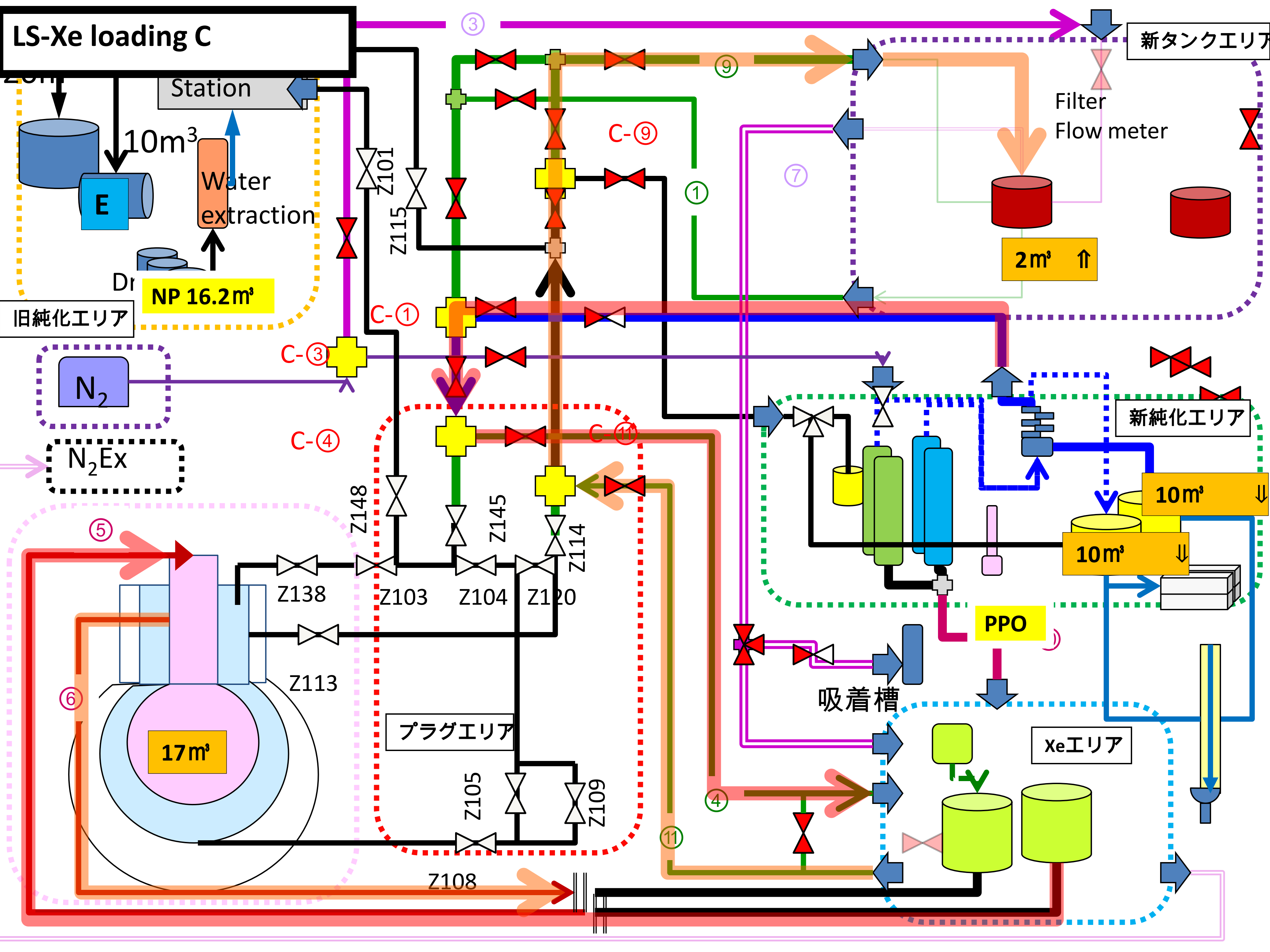
Mini Balloon is very thin so Xe loaded scintillator should have the same density as the KamLAND scintillator

Xe loaded LS		KamLAND LS
PC 17.7%		PC 20%
Decane 82.3%	=	Dodecane 80%
PPO(~2.7g/l)		PPO(1.36g/l)
Xe 3.0wt%		





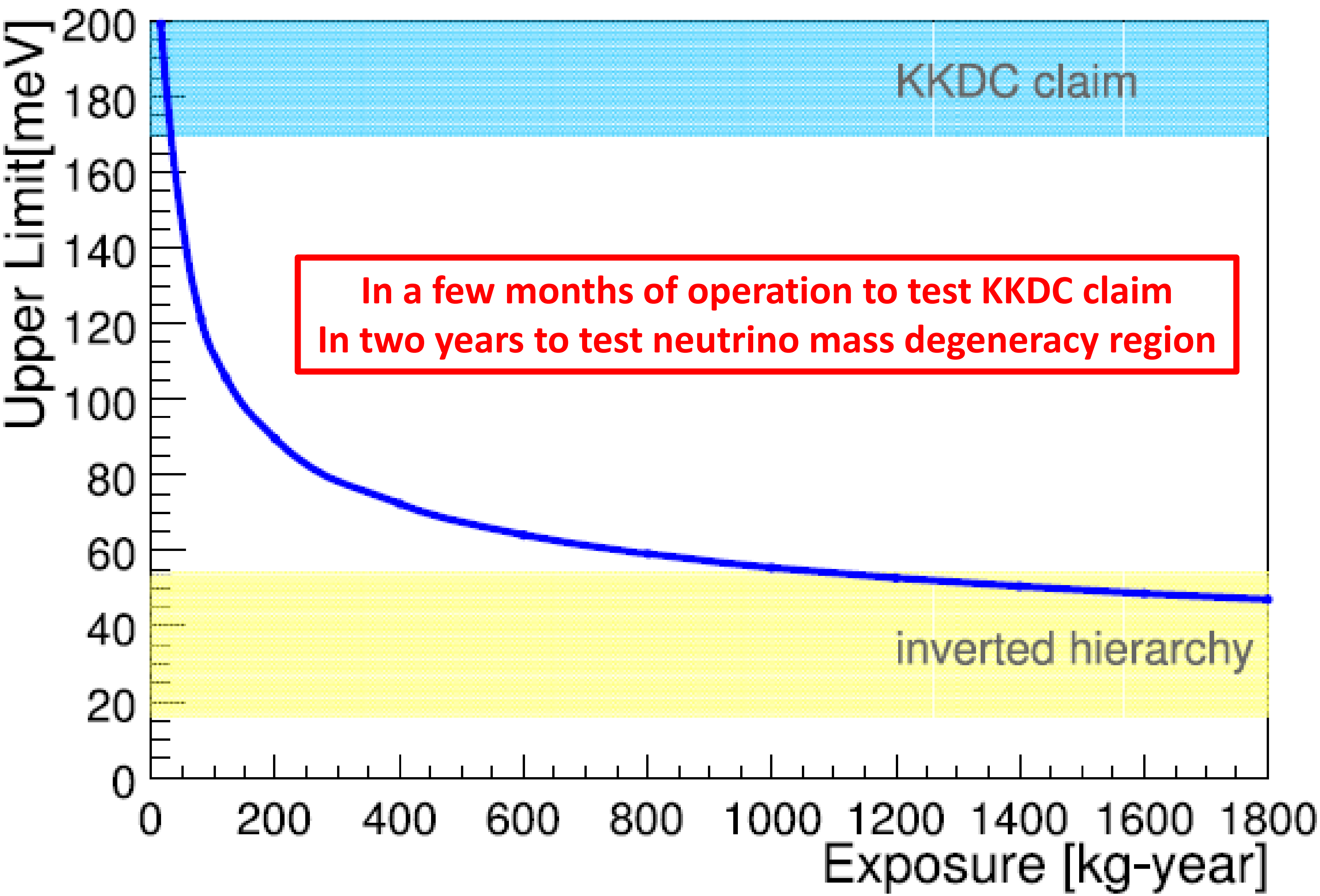




LS-Xe loading C
Station
10m3
Water extraction
E
NP 16.2㎥
旧純化エリア
N2
N2Ex
③
新タンクエリア
⑨
Filter
Flow meter
C-⑨
①
⑦
2㎥ ⇑
Z101
Z115
C-①
C-③
C-④
C-⑪
新純化エリア
10㎥ ⇓
10㎥ ⇓
PPO
吸着槽
⑤
⑥
17㎥
Z148
Z145
Z114
Z138
Z103
Z104
Z120
Z113
プラグエリア
Z105
Z109
Z108
④
⑪
Xeエリア

Scintillator Handling Infrastructure

KamLAND-Zen Sensitivity



Present Status and Plans

Xe handling system is in place

370 kg of ^{136}Xe are in the mine (50 kg are coming soon)

Xe LS system has been assembled

Mini Balloon is being made

Final Calibration for Reactor phase is ongoing

Scintillator mixing – July

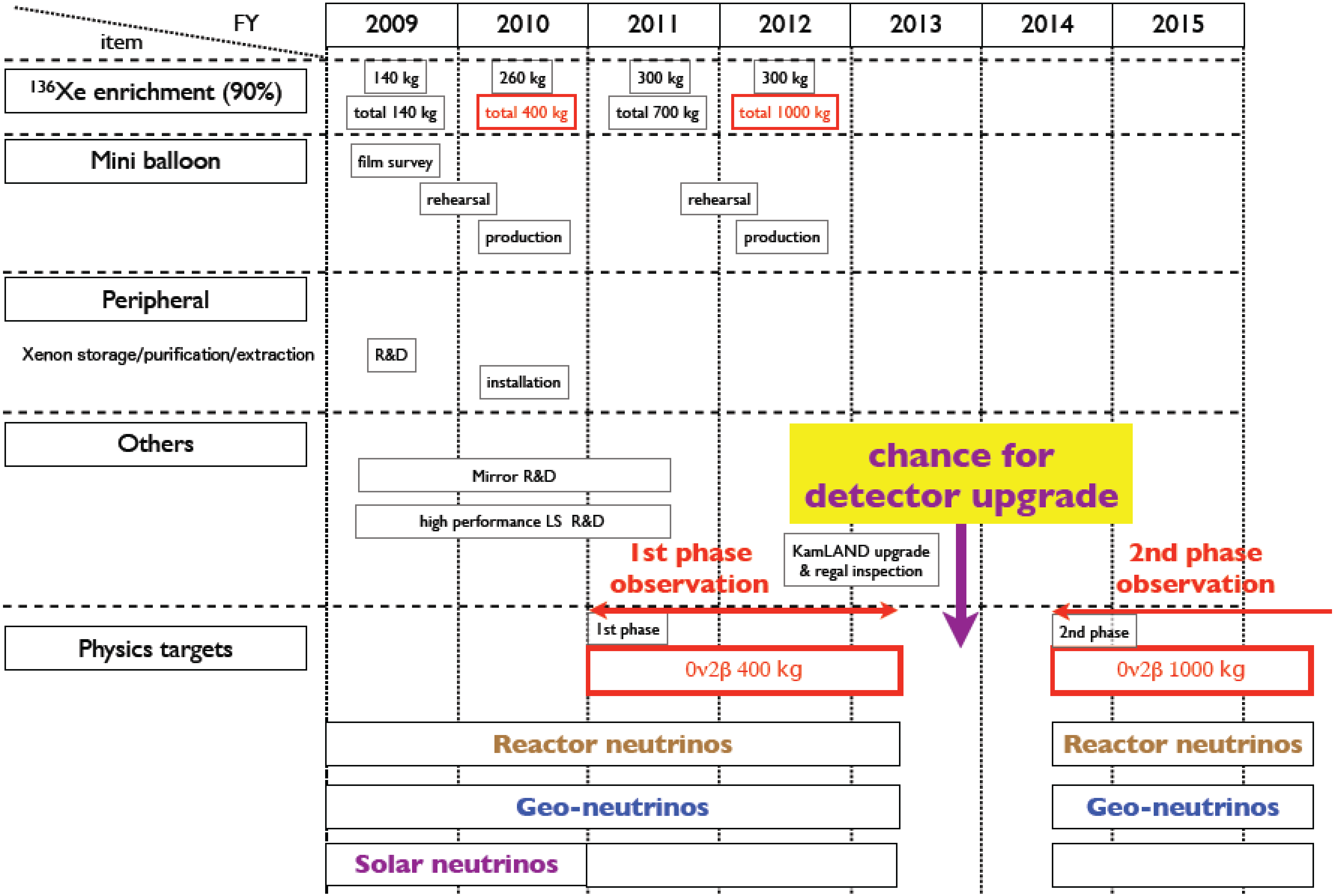
Chimney modification – July

Mini Balloon deployment and filing – August

Data Taking from September

First results later this year

KamLAND Future



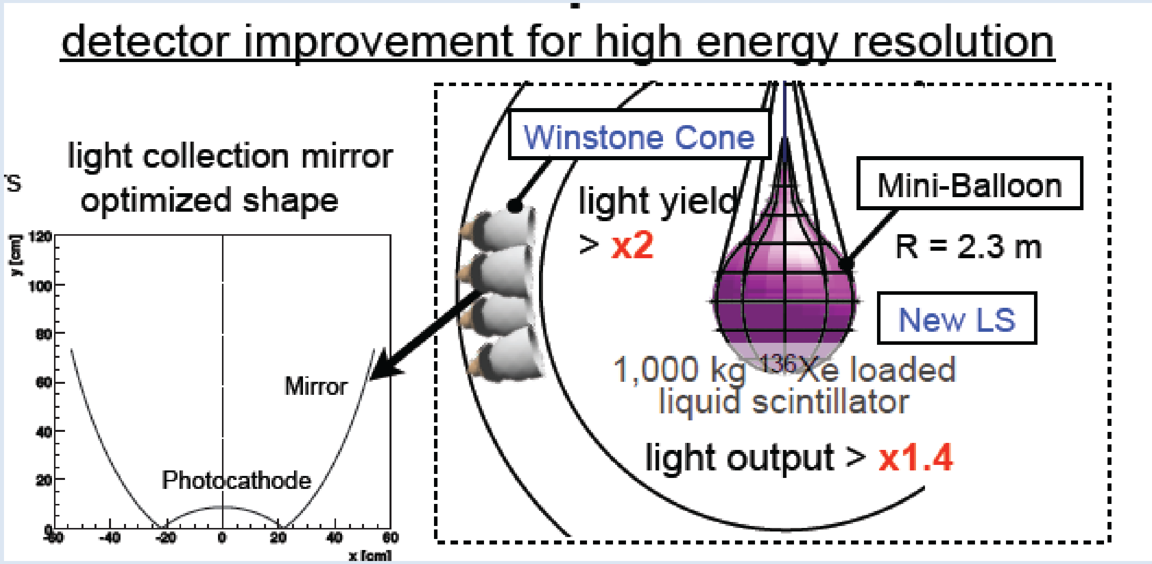
KamLAND2-Zen

More mass of the isotope 400kg →1000 kg.

Larger mini balloon → move favorable ratio of mass to balloon surface

Improve energy resolution (light collection)

Better energy resolution will decrease background from $2\beta2\nu$ decay and from $^{8}B_{\nu}$, ^{10}C



Aim is to have 20 meV sensitivity in 5 years

Resent development is that inspection in 2013 had been waived. Collaboration could decide to go for 1t experiment without energy resolution upgrade.

There are ongoing R&Ds to evaluate possibility to deploy in parallel crystals with 2b isotopes ($CdW0_4$, CaF_2, et. set.)

Conclusion

KamLAND made major contribution in study of neutrino oscillations.
It started new branch of science → neutrino geophysics

Now KamLAND is moving priorities from neutrino detection to the detection of no neutrinos.

400 kg ^{136}Xe experiment with sensitivity down to 50 meV for effective neutrino mass is about to start

We will continue to do Reactor, Geo Neutrino physics and Supernova watch in parallel

Stay Turned