Study of New Experiment (Double Beta Decay) with KamLAND

Week Interactions and Neutrinos (WIN'09)

Sep. 17, 2008

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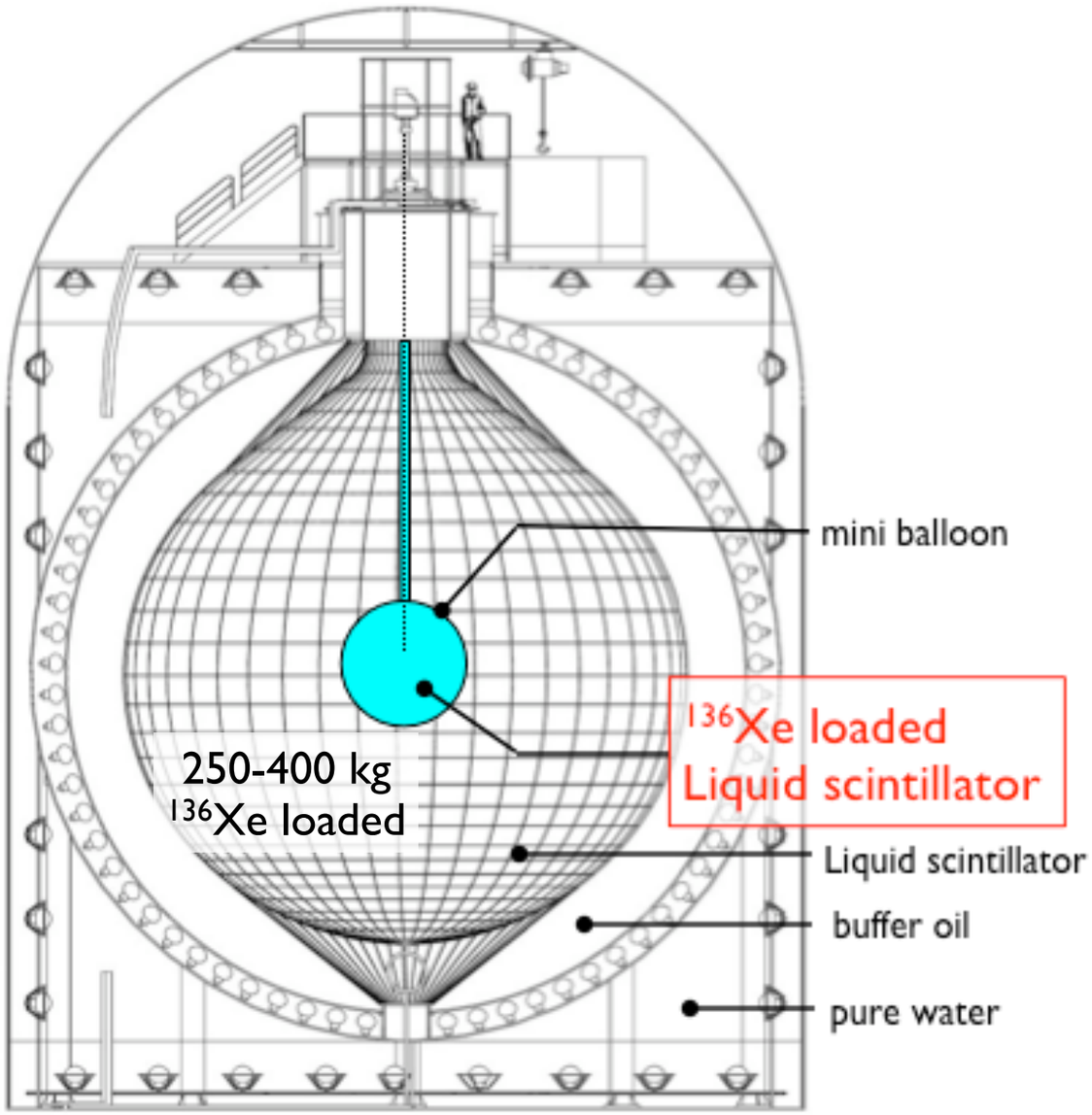
0νββ search with KamLAND

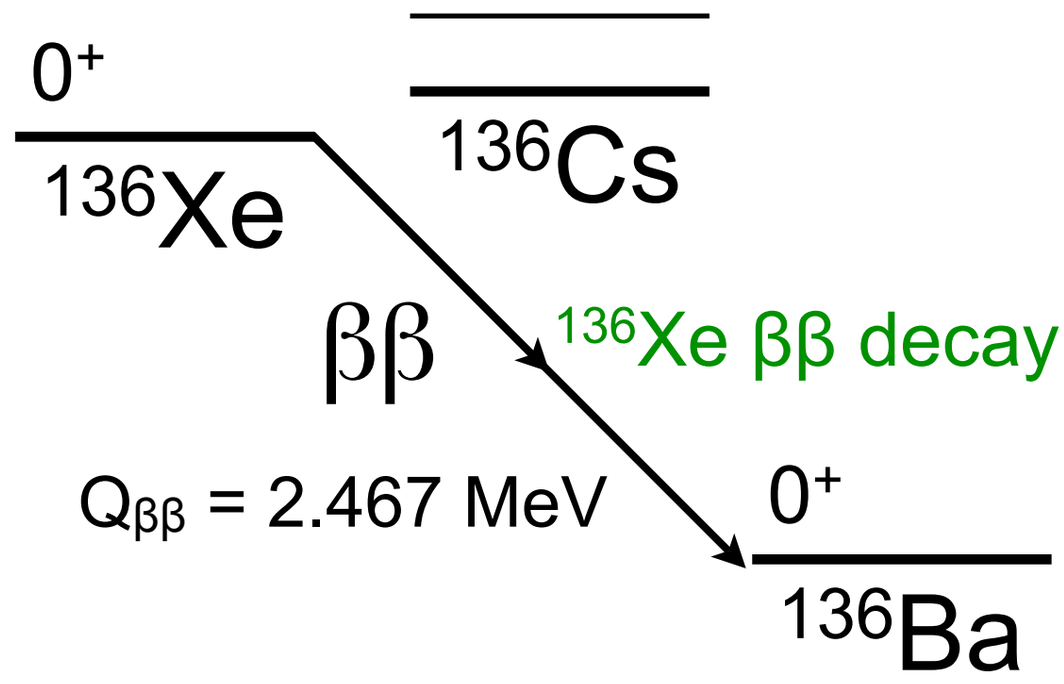
^{136}Xe loaded LS in KamLAND



1st phase

double beta decay

$$(A, Z) \longrightarrow (A, Z+2) + 2e^- + (2\overline{\nu}_e)$$



Why use Xe?

- Isotopic enrichment, purification established
- Soluble to LS more than 3 wt%, easily extracted
- Slow 2νββ ($T_{1/2} > 10^{22}$ years) requires modest energy resolution

Merit of using KamLAND

(1) Ultra low radioactivity environment based on ultra pure LS and 9m radius active shield

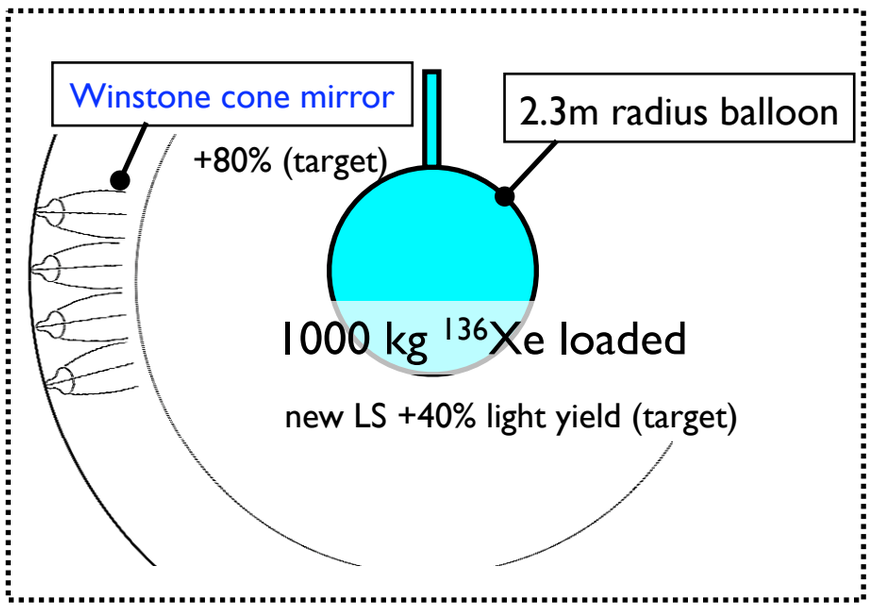
U: $<3.5\times10^{-18}$ g/g Th: $<5.2\times10^{-17}$ g/g

(2) no modification to the detector is necessary to accommodate DBD nuclei

(3) high sensitivity with low cost (~6M$, budget secured)

~60 meV with 1.5 year

(4) reactor and geo- antineutrino observations continue



2nd phase

(5) high scalability (2nd phase)

1000 kg ^{136}Xe, improvement of energy resolution with light concentrators and brighter LS (~30M$)

~25 meV with 5 years

R & D Items

(1) Xenon loaded LS with the same density, luminosity, transparency

done

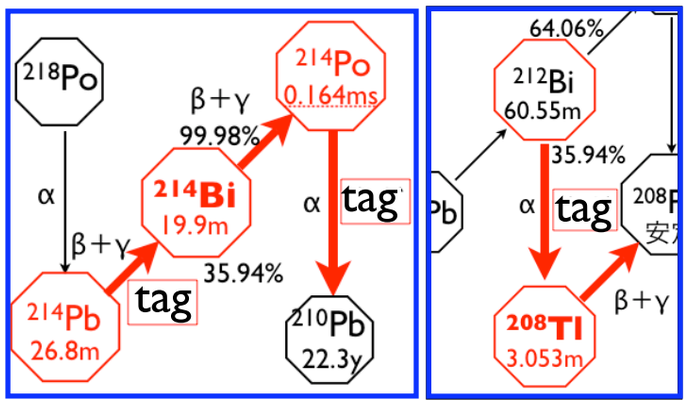
KamLAND LS	
dodecane	80%
pseudo-cumene	20%
PPO	1.36 g/liter

Xenon loaded LS	
decane	81.8%
pseudo-cumene	18.2%
PPO	2.7 g/liter
Xenon	2.5 wt%

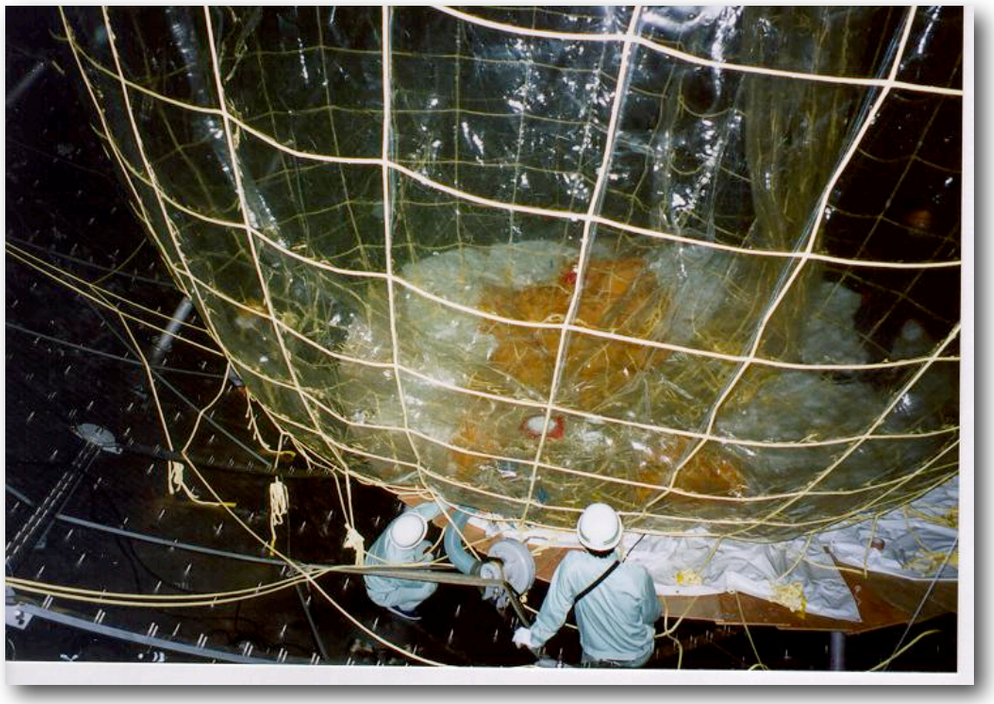
soluble up to 3 wt% at 10 ℃

(2) 2.7~4 m φ Mini-balloon

target { low radioactivity (10^{-13} g/g U/Th)
thin (25μm)



experience of 13 mφ balloon



target balloon image

R & D Items

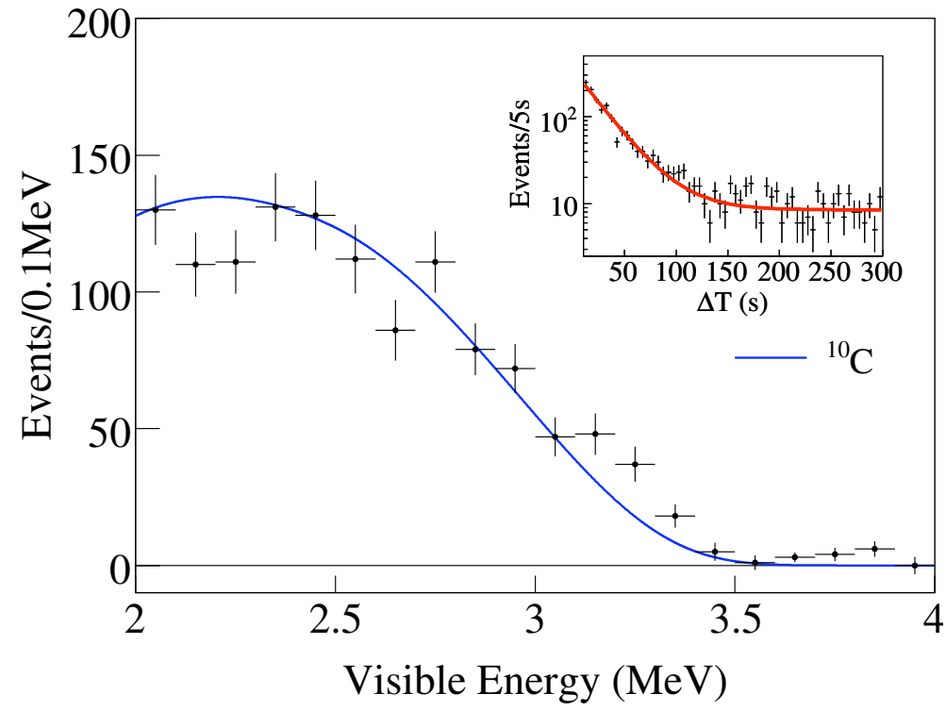
(3) Xenon purification, storage, extraction etc

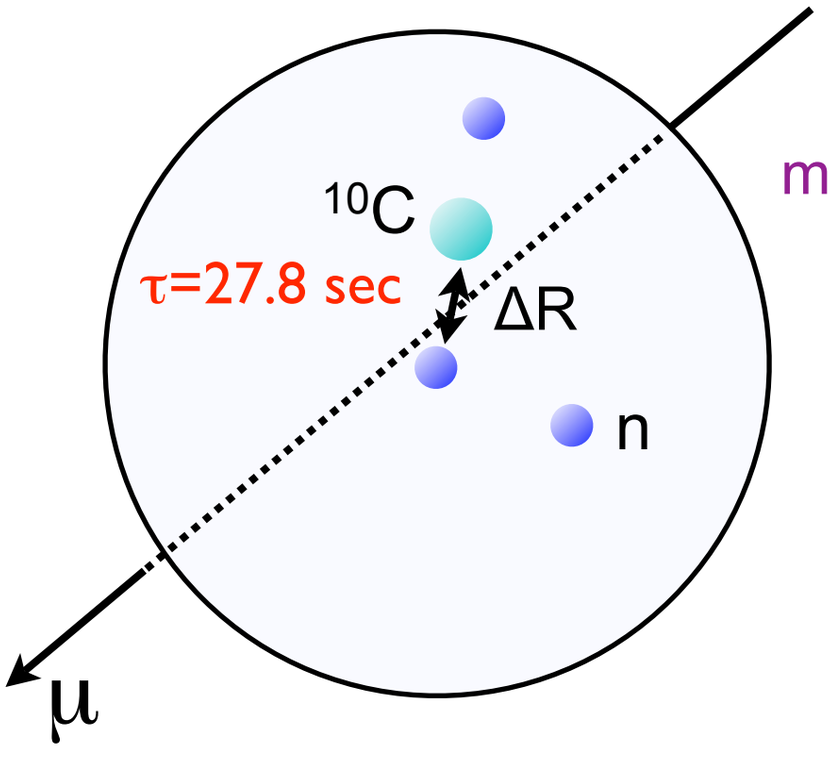
experiences of big distillation system, high pressure nitrogen production

(4) Cosmogenic background rejection with dead-time free electronics

^{10}C τ = 27.8 sec, Q = 3.65 MeV

R = 21.2 +- 1.8 / kton-day

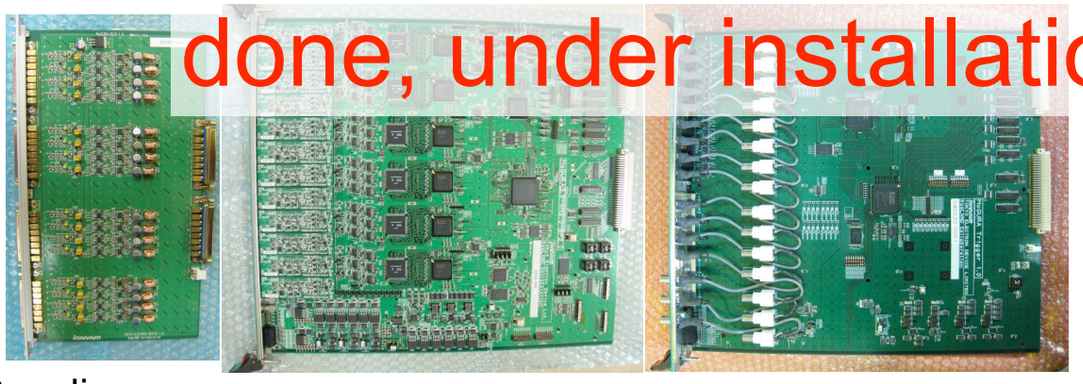




muon spallation
(target ^{12}C)

factor 20 reduction with neutron tagging

done, under installation



Baseline restorer and signal splitter

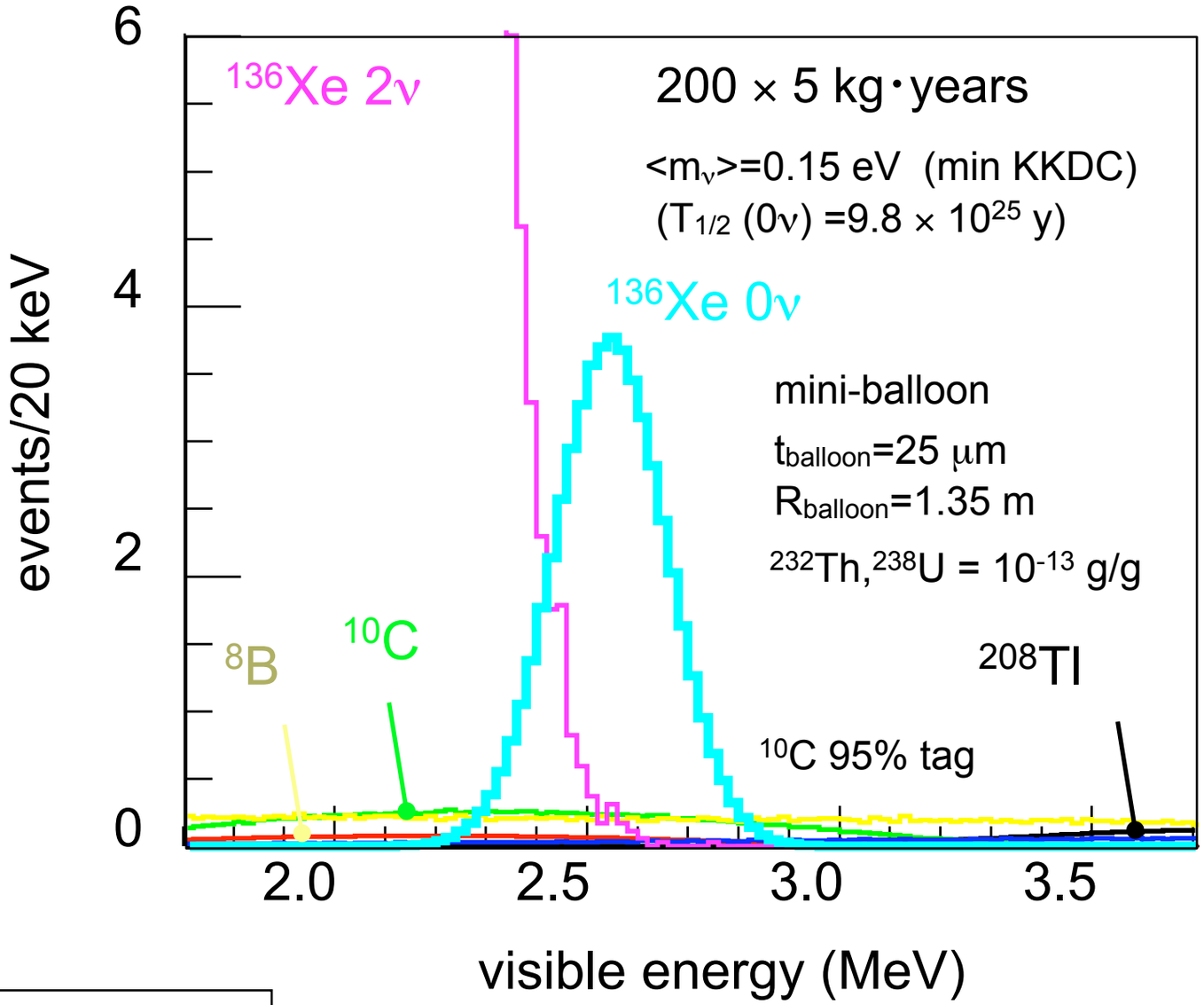
1GHz FADC +
3 range 200 MHz FADC
for each channel

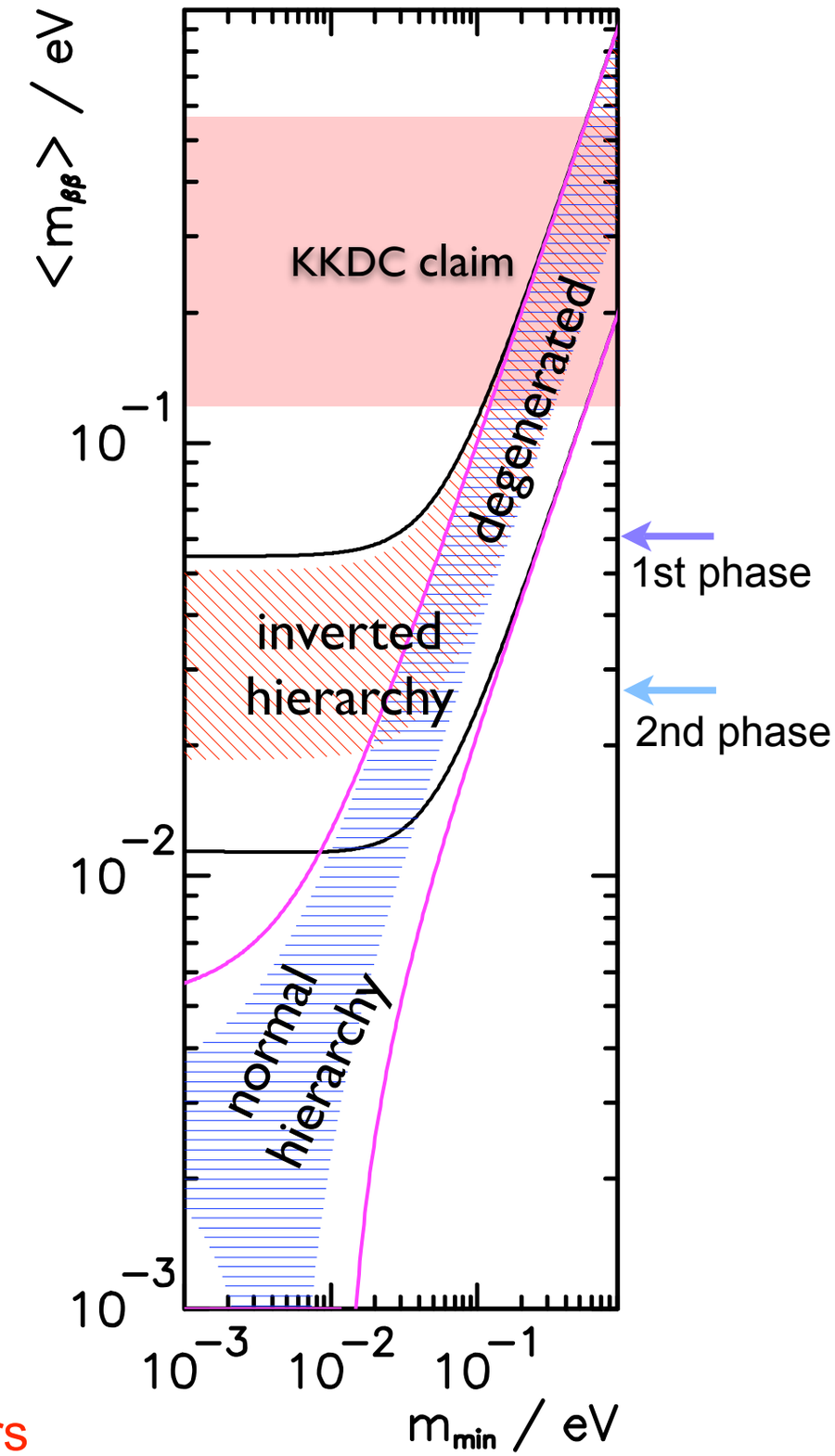
Trigger module

Sensitivity for Neutrino Mass

1st phase

KKDC claim, degenerated hierarchy test





2nd phase

inverted hierarchy test

Target sensitivity of the 2nd phase is ~25 meV with 5 years

Project Time Line

item \ FY	2009	2010	2011	2012	2013	2014	2015
^{136}Xe enrichment (90%)	140 kg total 140 kg	260 kg total 400 kg	300 kg total 700 kg	300 kg total 1000 kg			
Mini balloon	film survey rehearsal production		rehearsal	production			
Peripheral							
Xenon storage/purification/extraction	R&D	installation					
Others							
Mirror R&D							
high performance LS R&D							
KamLAND upgrade & regal inspection							
Physics targets							
1st phase							
0ν2β 250–400 kg							
2nd phase							
0ν2β 1000 kg							
Reactor neutrinos							
Geo-neutrinos							
Solar neutrinos							

Summary

- We studied the possibility of 0νββ search with KamLAND using the Xe loaded LS
- The sensitivity for the neutrino mass was evaluated

1st phase : KKDC claim, degenerated hierarchy test

2nd phase : inverted hierarchy test

- R&D items for the ^{136}Xe experiment

(1) Xenon loaded LS with the same density, luminosity, transparency

(2) 2.7~4 m φ Mini-balloon

(3) Xenon purification, storage, extraction etc

(4) Cosmogenic background rejection with dead-time free electronics