Study of Ocean Bottom Detector(OBD) for observation of geo-neutrinos from the mantle

Taichi Sakai (Tohoku Univ. RCNS)

XIX International Workshop on Neutrino Telescopes

Geo-neutrino

Electron-antineutrinos from natural radioactive decays of Earth

Geo-neutrinos

$$^{238}\mathrm{U} \rightarrow {}^{206}\mathrm{Pb} + 8\alpha + 6\mathrm{e}^- + 6\bar{\nu}_\mathrm{e} + 51.7\,\mathrm{MeV}$$

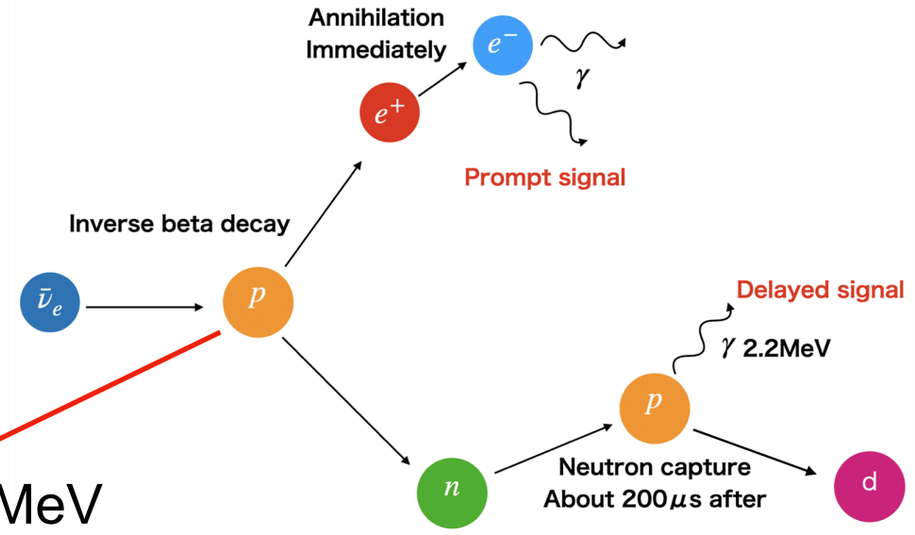
$$^{232}\mathrm{Th} \rightarrow {}^{208}\mathrm{Pb} + 6\alpha + 4\mathrm{e}^- + 4\bar{\nu}_\mathrm{e} + 42.7\,\mathrm{MeV}$$

$$^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + \mathrm{e}^- + \bar{\nu}_\mathrm{e} + 1.311\,\mathrm{MeV}\ (89.28\%)$$

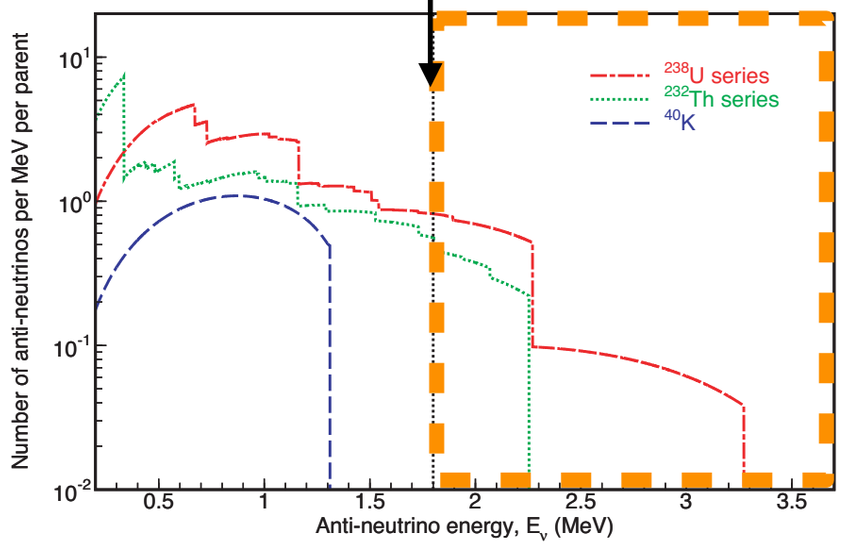
*Only geo-neutrinos from ^{238}U &^{232}Th are detectable right now

*^{40}K neutrino detection needs another technology

[Delayed coincidence of inverse β-decay]

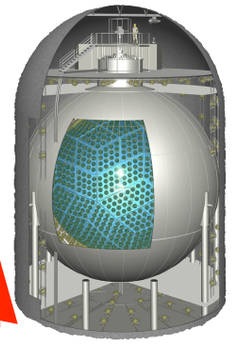


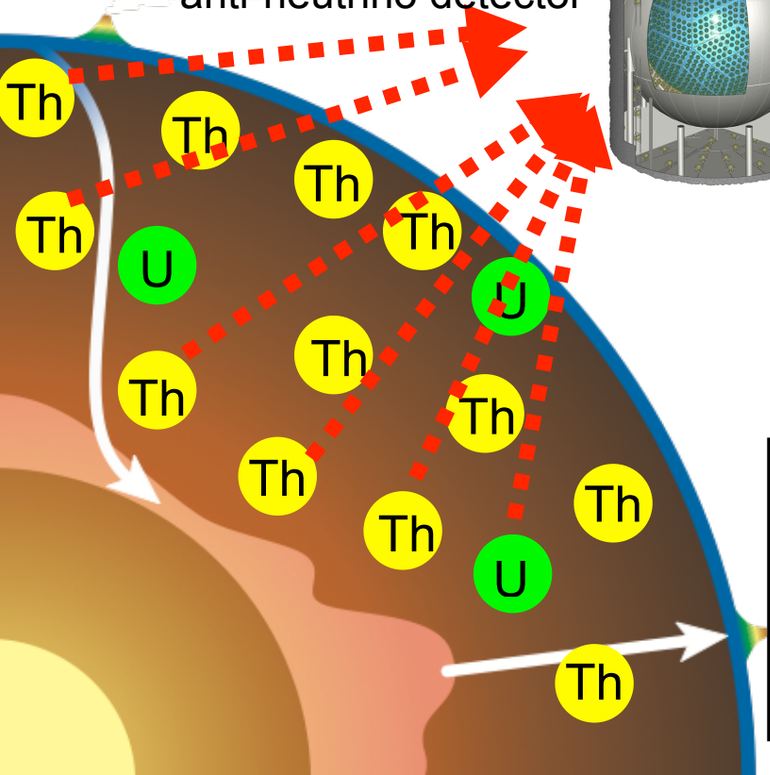
Energy threshold, 1.8 MeV



$\bar{\nu}_e$ $4.1 \times 10^6/\mathrm{cm}^2/\mathrm{sec}$

anti-neutrino detector





Only way to directly measure amount of radiogenic heat sources

[Achievement so far]

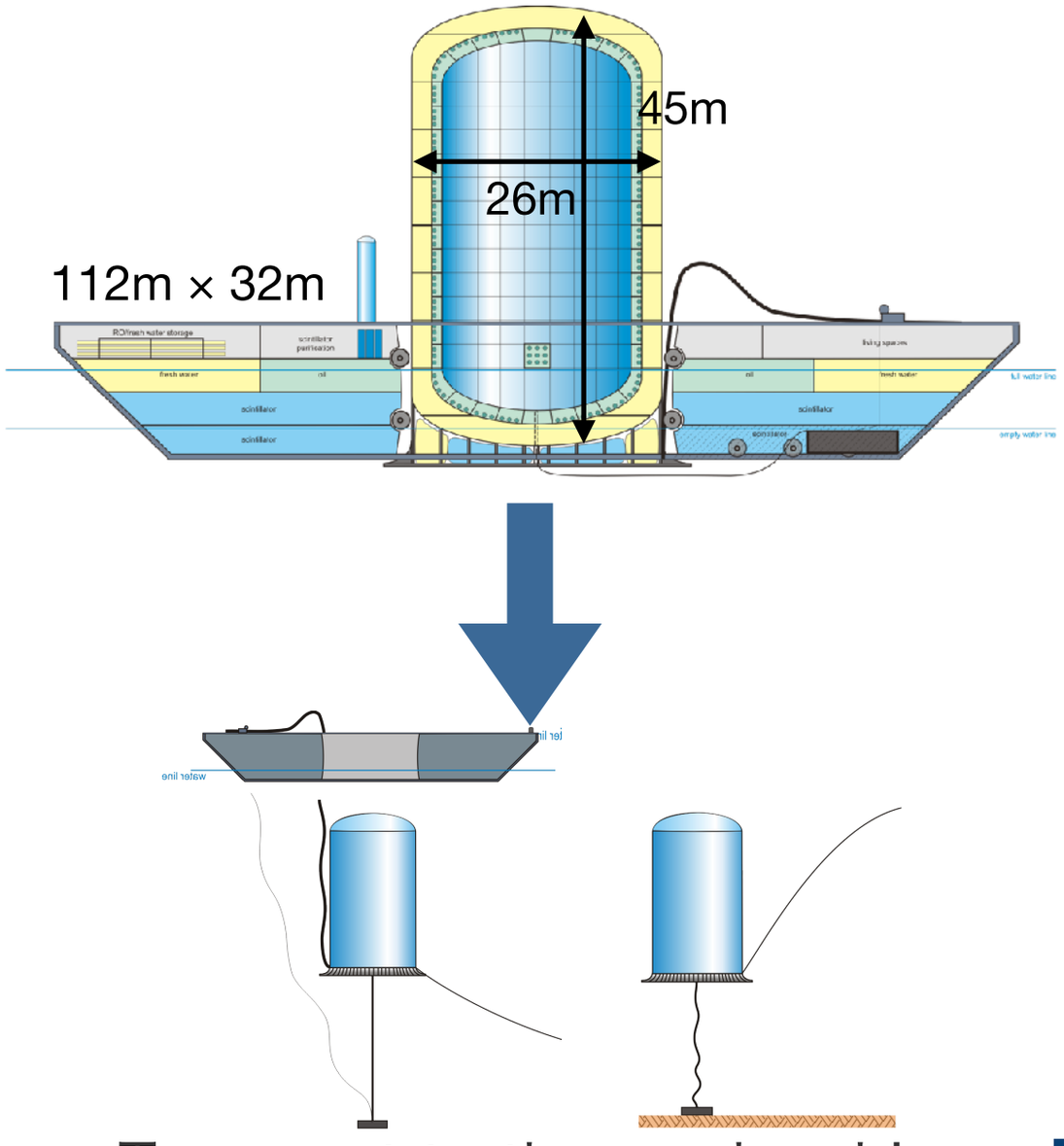
* **Total radiogenic** heat the Earth
* Limit on **Earth models**
* observation- crust model = **mantle**
  Large uncertainty
* U/Th ratio

[Next target]

Direct measurement of mantle geo-neutrino

What is Ocean Bottom Detector?

“Hanohano”:detector design @Univ. Hawaii 2005



Transport to the sea by ship and sink to the seafloor at the installation site

In 2019,
*JAMSTEC&Tohoku Univ.
joint research started

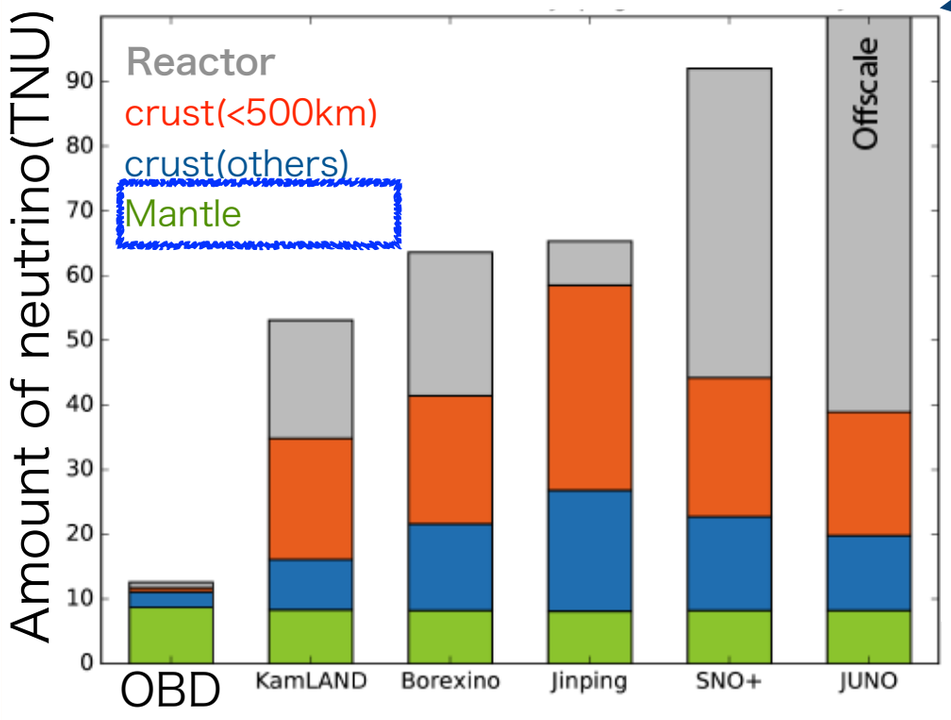
*Japan Agency for Marine-Earth Science and Technology

Primary goal: observe mantle geo-neutrino in the sea

*	Detector size	: 10-50 kt (final goal)
*	Location	: 2~5 km deep sea, offshore Hawaii is leading candidate
*	Period	: over 1year/1place

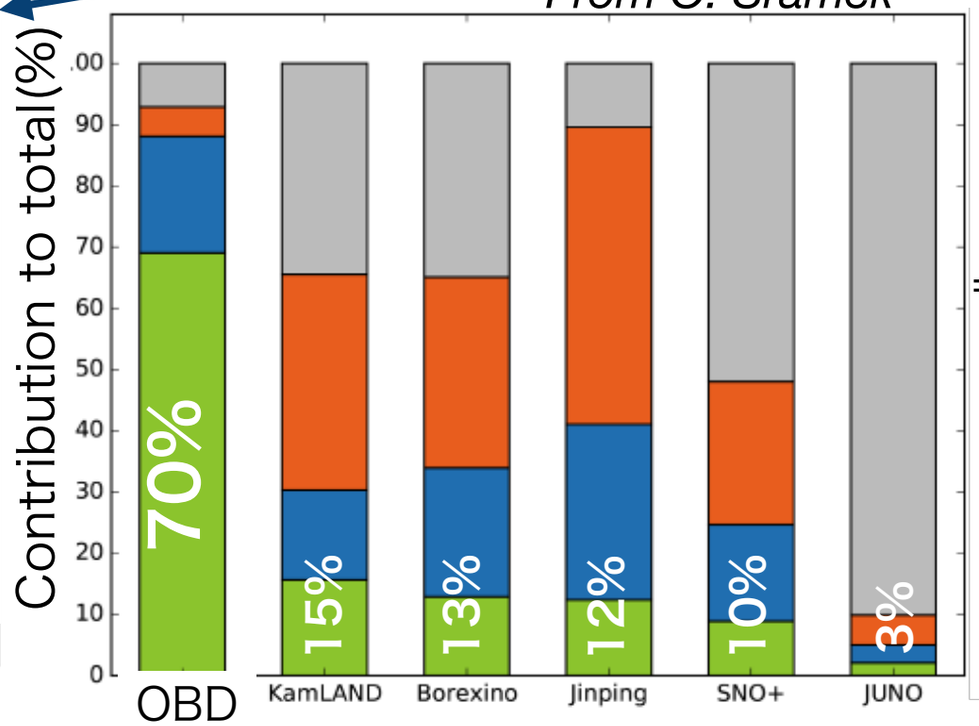
Unique features of OBD

1.small contribution from crust



(3 5 4.5 TNU)

From O. Sramek

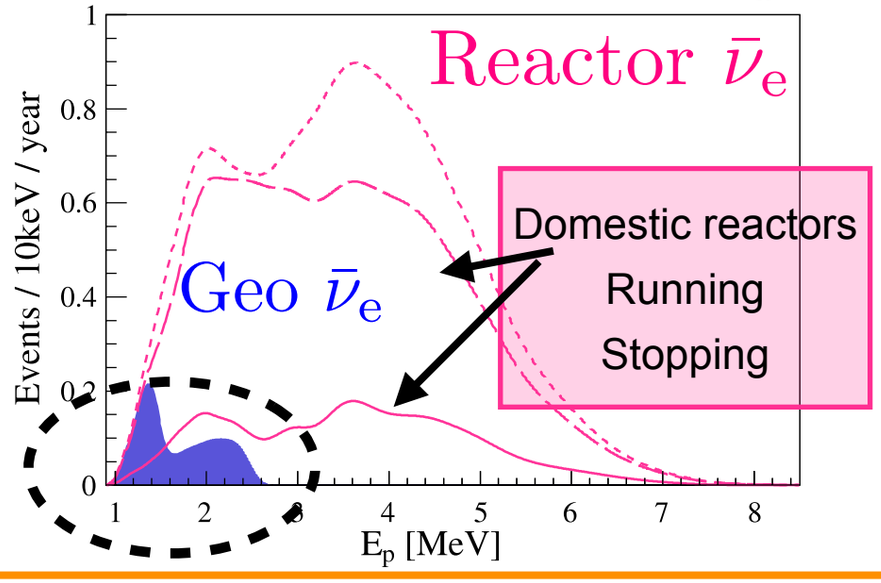


TNU:
terrestrial neutrino unit
=1event/10^{32}protons/year

Oceanic crust is thin and less U and Th

2.keeping distance from reactor

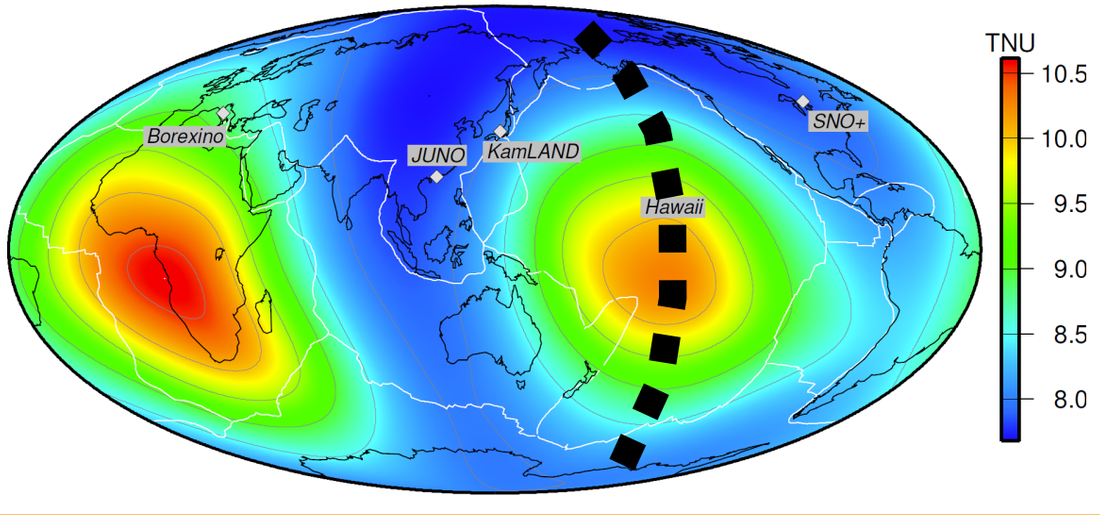
Simulation @KamLAND



3.observe at multiple points, map the mantle

Šrámek et al (2013) EPS, 10.1016/j.epsl.2012.11.001

Mantle geo-neutrino flux



OBD future prospects

2019 funded 2020~2022 ~20kg ~1-10t ~1.5kt ~10-50kt

Maturity of science

First clear mantle signal

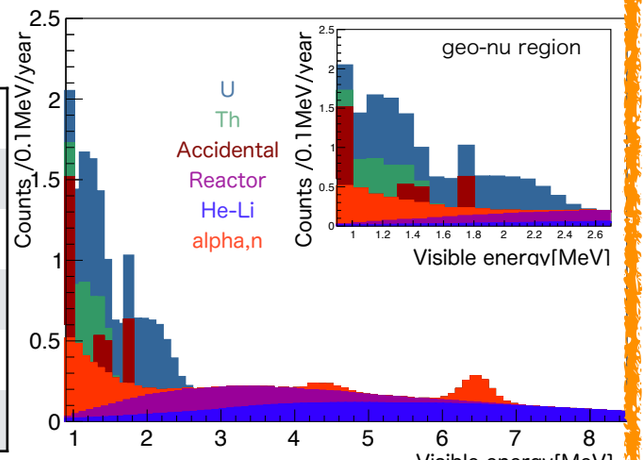
Hawaii is candidate position
Sensitivity for mantle geo-ν
3 year: 3.5σ

Signal

Signal	rate[event/year]
U	7.1
Th	1.8
total geonu	8.9
U mantle	5.3
Th mantle	1.3
total mantle	6.6

Background

Source	events [/year]	Geonu-region
Reactor	4.4	1.6
Accidental	2.4	2.4
He_Li	6.2	0.5
Alpha,n	3.6	2.6
total	16.6	7.1



OBD project has started with JAMSTEC* & Tohoku Univ.

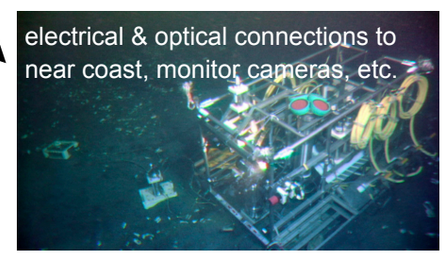
*Japan Agency for Marine-Earth Science and Technology

Technical demonstration & environment measurement in the sea

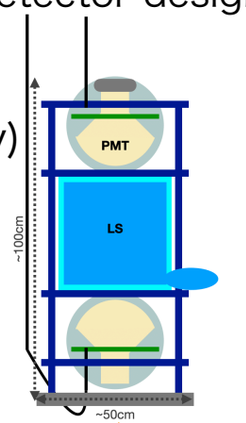
deep sea neutrino & muon flux, ocean water density & temperature, radioactivity
→ input parameters for ~1.5 kt detector design

Technical test & world's first measurement in the ocean with LS detector

*install detector into 1km seafloor(JAMSTEC's Hatsushima Observatory)
*technical developments are in progress
-low-impurity PMT shield
-LS optimization for ocean environment
-DAQ system & power supply



Detector design



Summary

* **Geo-neutrino**
  * **Directly define power to drive the Earth's engine**
  * **Interdisciplinary community has enhanced the research field**
* **Ocean Bottom Detector (OBD): Breakthrough**
  * **Direct measurement of mantle geo-neutrinos**
  * **Multidisciplinary detector: geoscience, particle physics mantle drilling, biology etc.**