Ocean Bottom Detector

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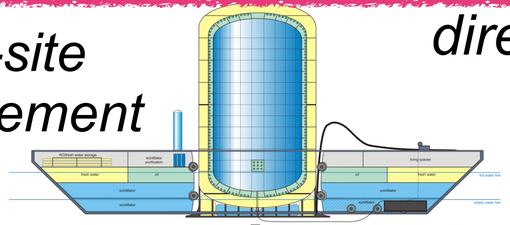
Neutrino Geoscience: Current and Future

what we need

improved accuracy of measurement & modelling

multi-site measurement



detector in the Ocean

directional sensitive detector

new type detector

current generation → **next** generation

total radiogenic heat in the Earth — ☑ Measuring

resolving vertical and horizontal flux differences

Th/U ratio — ☑ Measuring — **Next Target!**

Directly

distinguishing mantle contribution — ☑ Measuring

detecting K geo-neutrino

what we learn

first measurement in **2005**

OBD: breakthrough beyond modern land-based detector transforming our vision of deep Earth

OBD Motivations

- **Direct Measurement of Mantle**

  need to be far from <u>crust</u>
  can be far from <u>reactors</u>

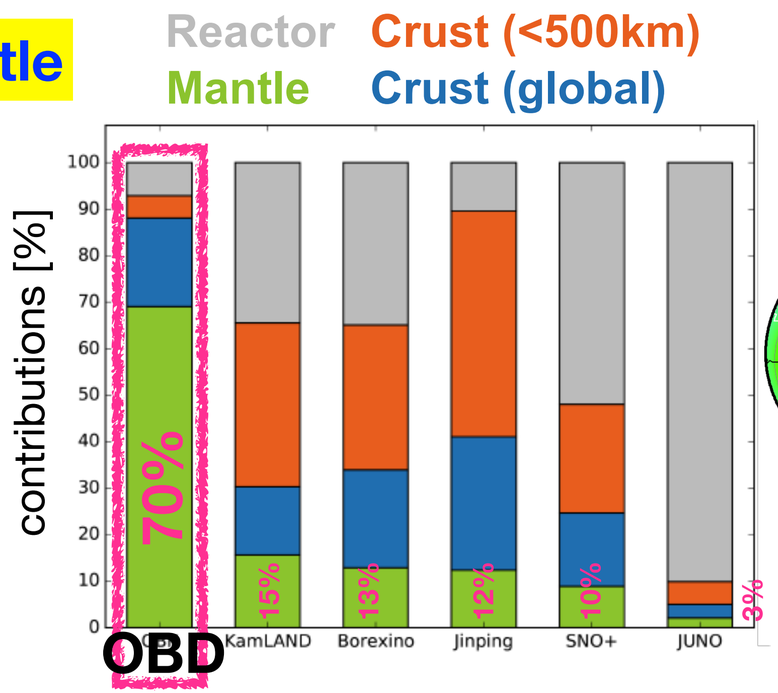
- **Multi-site Measurements**

  Solve the mystery of deep Earth!

- **Multidisciplinary Detector**

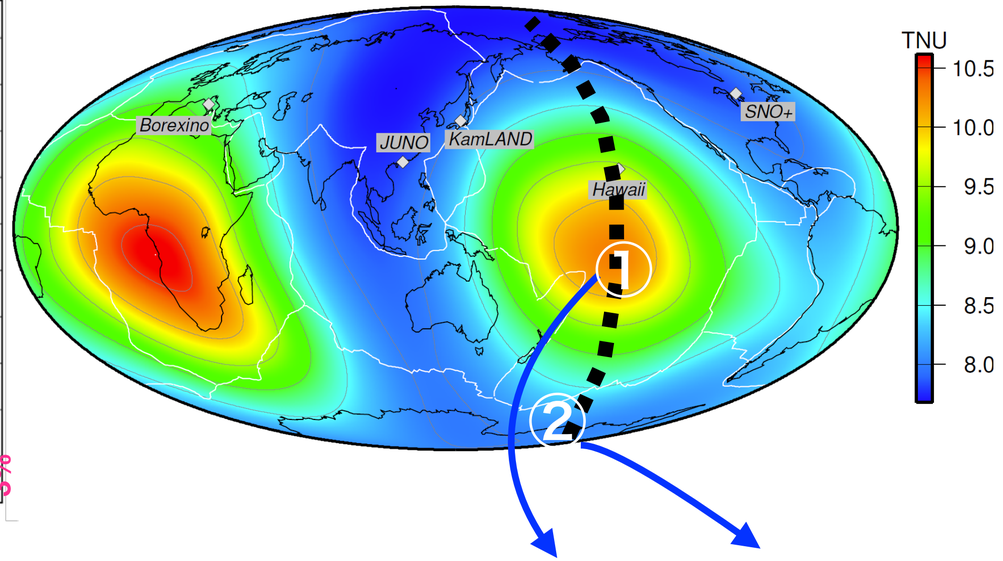
  <u>Physics</u>, Geoscience, Mantle drilling, Biology, New technology,…

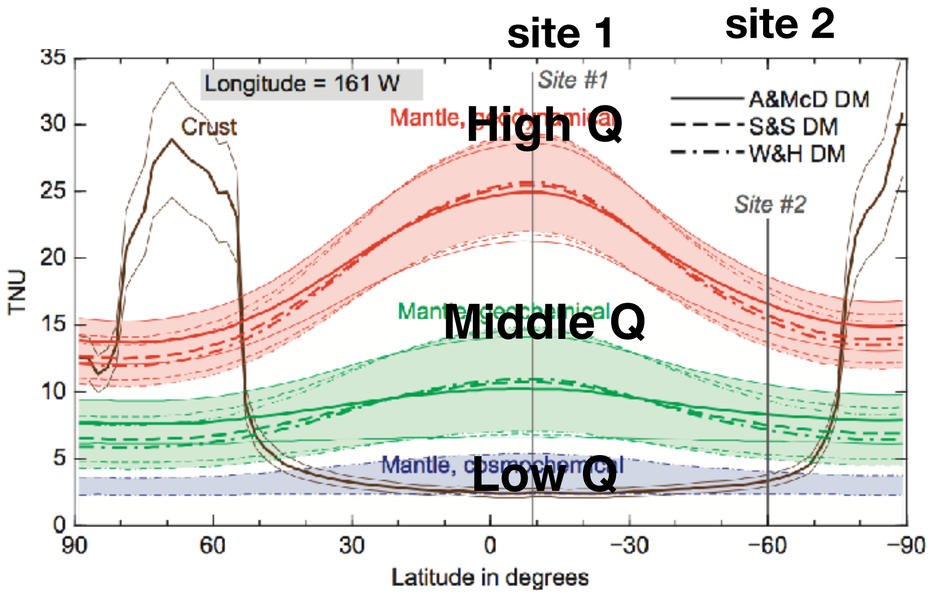
Physics :
- multi baseline measurement of reactor neutrinos
- astro particle physics
- dark matter measurement with less-neutron background
  etc.



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

Mantle Geoneutrino Flux



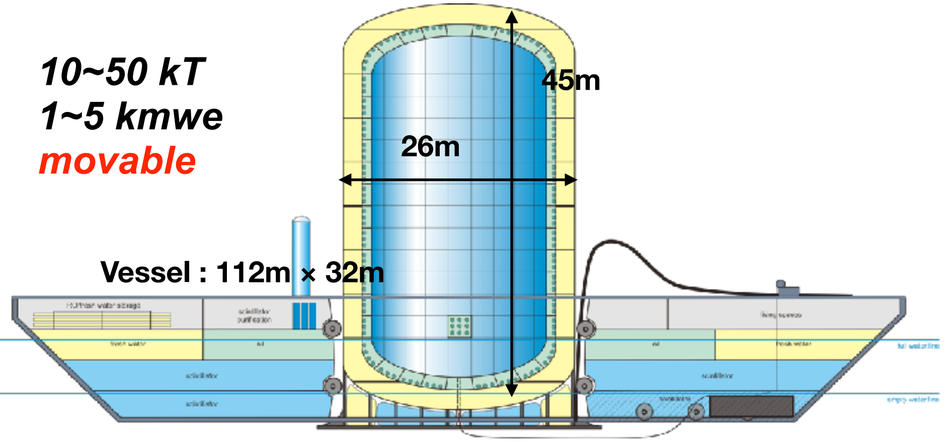


OBD Present & Future

2005 — No progress… — 2019 — 2020-2022 (funded) — ~20 kg — 1-10 t — ~1.5 kt — 10-50 kt

"Hanohano" 2005

10~50 kT
1~5 kmwe
movable



U. Hawaii & Makai Ocean Engineering

Technical tests and detector design

OBD project has started with JAMSTEC* & Tohoku U.!

* Japan Agency for Marine-Earth Science and Technology

OBD Present & Future

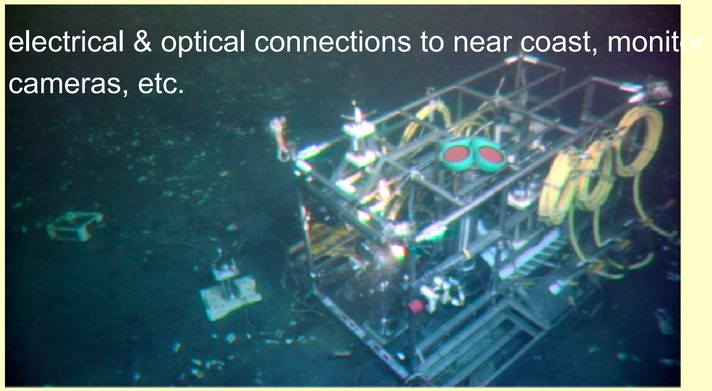
2005 No progress… 2019 2020-2022 funded

~20 kg 1-10 t ~1.5 kt 10-50 kt

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

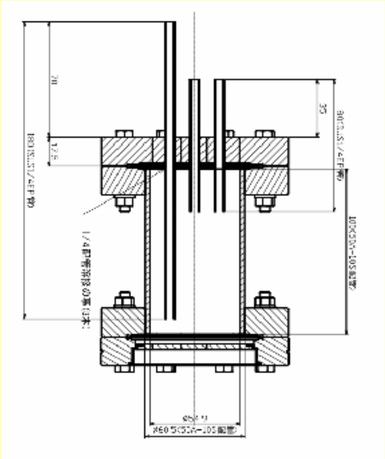
* Install detector into **~1km seafloor** (JAMSTEC's Hatsushima Observatory), take data for **several months**
* Technical developments are in progress.
  * low-impurity PMT shield : clean glass or acrylic, strength test will be done on Jan. 2021 at JAMSTEC
  * LS optimization for seafloor environment : experimental device will be ready next week
  * DAQ system & power supply
  * deployment, recovery, maintenance, redeploy

Hatsushima Observatory

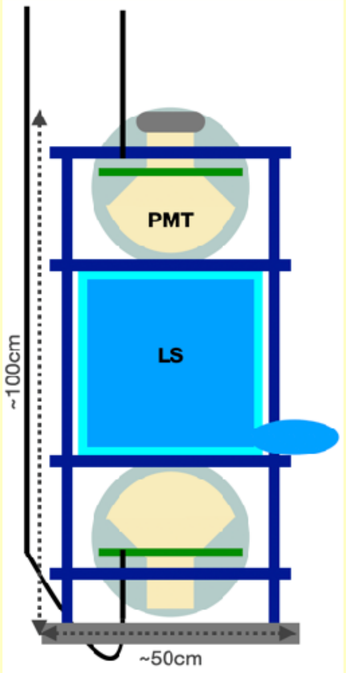


High-pressure experimental water tank at JAMSTEC

LS optimization experiment



detector design



OBD Present & Future

2005 No progress… 2019 2020-2022 funded

~20 kg 1-10 t ~1.5 kt 10-50 kt

Maturity of science

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

First clear mantle signal

* Detector simulation study is in progress.
* Hawaii is possible position.
* Sensitivity for **mantle geo-neutrino**

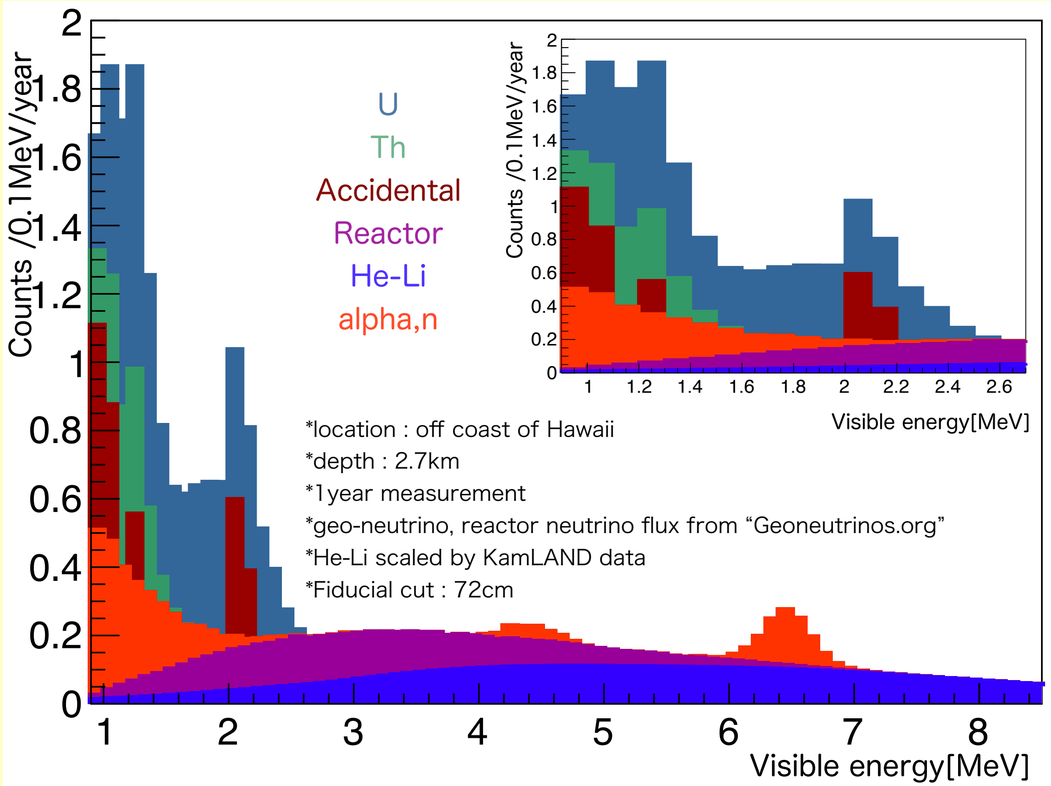
1-year : 1.8 σ
3-year : 3.4 σ

Signal

Signal	rate[event/year]
U	7.4
Th	1.8
total geonu	9.2
U mantle	5.5
Th mantle	1.3
total mantle	6.8

Background

Source	events [/year]	Geonu-region
Reactor	4.5	1.7
Accidental	1.8	1.8
He_Li	6.2	0.6
Alpha,n	3.6	2.6
total	16.1	6.7



Summary

- For two centuries we have asked what is the energy that drives the Earth?

- Geoneutrinos are unique and new tool to measure directly the Earth's interior.
  - **Only way to measure amount of radioactive elements in the Earth**

- To date, physics experiments have shown the usefulness of geoneutrinos.
  - **Interdisciplinary community has furthered its connection over these past 15 years.**

- **"Neutrino Science" : <u>collaborations between geology, physics and beyond</u>**
  - **Ocean Bottom Detector (OBD) = Breakthrough**
  - **OBD can test fundamental particle physics, reactor baseline studies, etc.**

OBD's Primary Goal :

<Transformative insights>

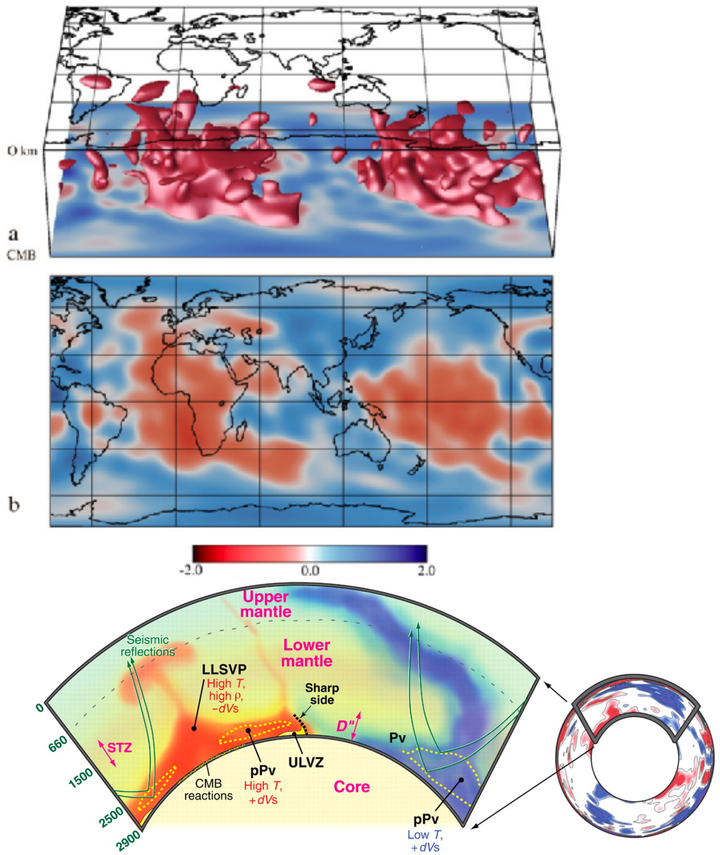
- **map the mantle**
- **constrain the planet's cooling history**

Backup

Why geo-neutirno?: Big questions

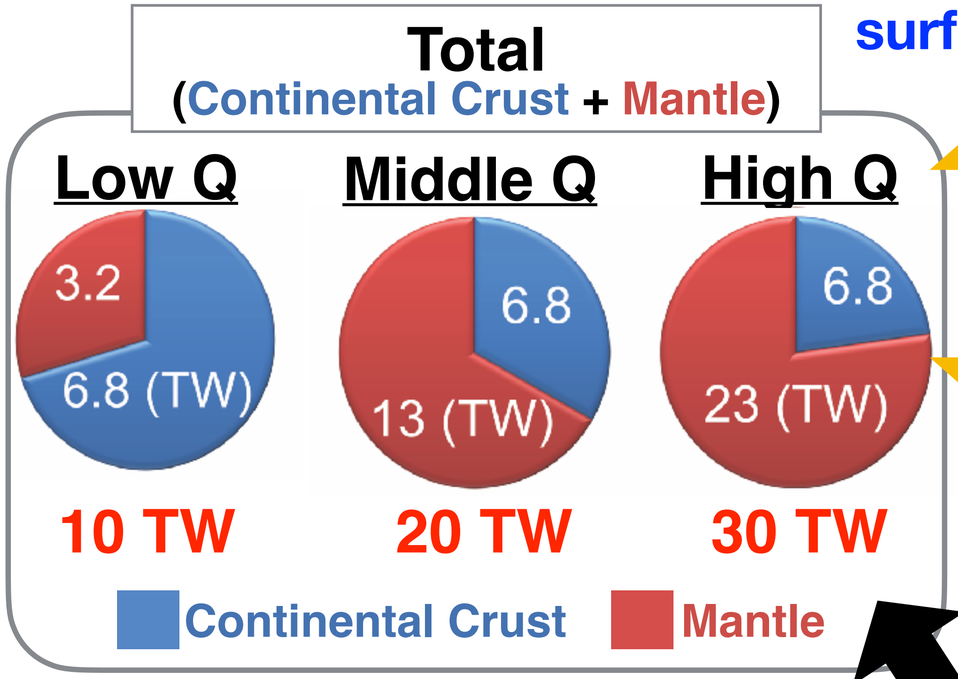
What is in the mantle?

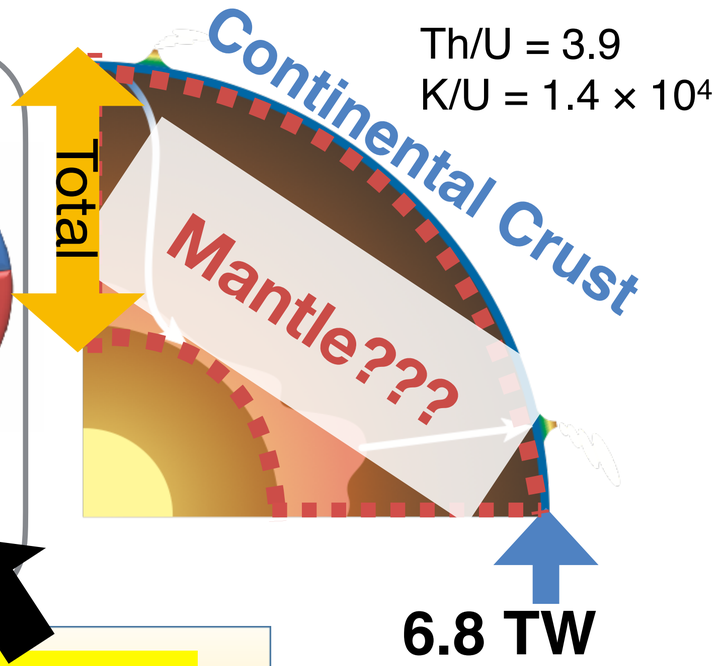
Many seismically imaged structures and chemical heterogeneities in the mantle



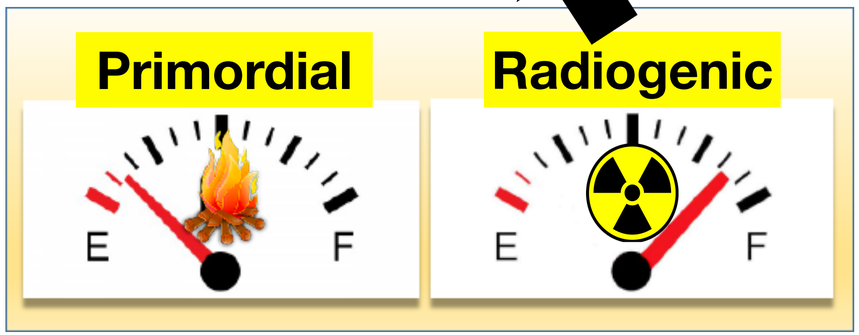
How much fuel is left to drive Plate Tectonics?

surface heat flow : 46 ± 3 TW





Th/U = 3.9
K/U = 1.4 × 10^4



Geo-neutrino can directly define power to drive the Earth's engine

Multi-site Measurement + OBD

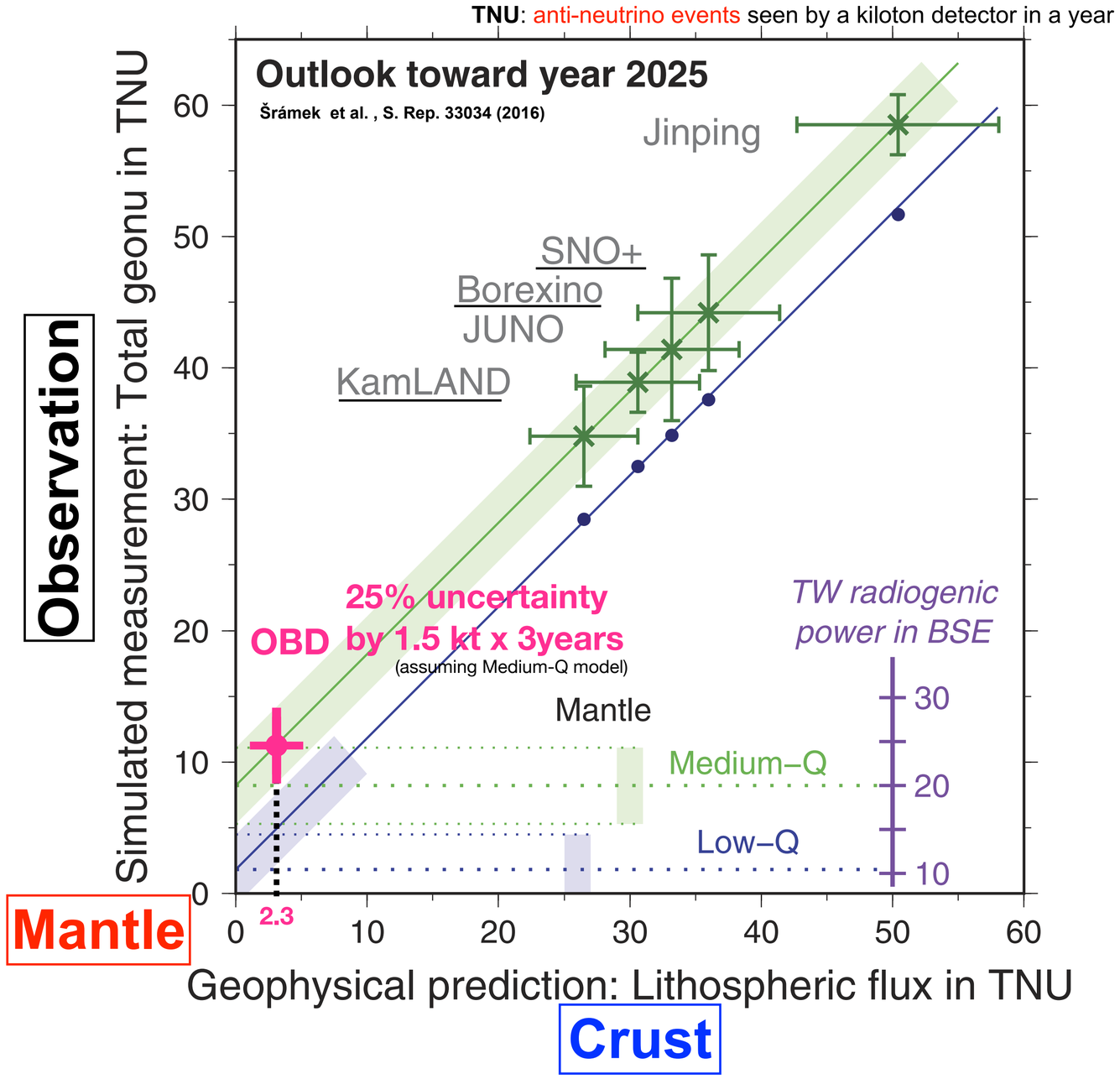
Observation = **Crust** + **Mantle**

(y = x + b)

Near Future…

3 multi-site measurements can constrain mantle contribution.

Crust estimation needs to be accurate.

+ OBD

OBD can directly measure mantle contribution.