# JUNO's Sensitivity to Geoneutrinos


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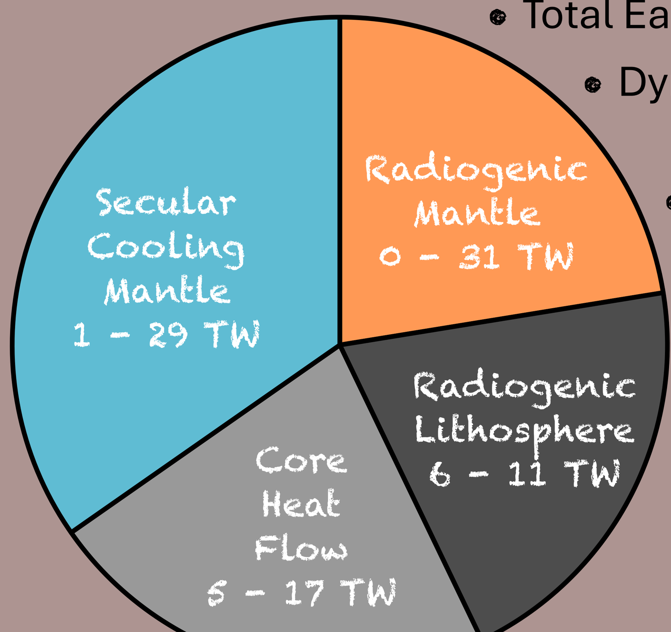
## Why Geoneutrinos?




Credit to [2] and [3]

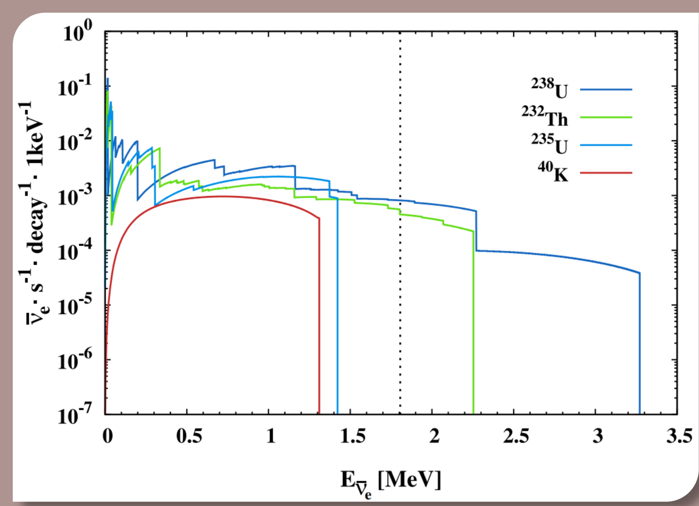
- Total Earth's heat loss measured at 41 – 47 TW [1]
- Dynamical processes must correspond to the measured budget
- Radiogenic Heat can be constrained if element abundances are known
- **B**ulk **S**ilicate **E**arth Models provides estimation of elements abundances and radiogenic heat

BSE = Lithosphere + Mantle

Directly Studied — Not easy to access

Heat Producing Elements — Geoneutrinos — Radiogenic Heat

$$^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + 1e^- + 1\bar{\nu}_e + 1.32\ \mathrm{MeV}$$
$$^{238}\mathrm{U} \rightarrow {}^{206}\mathrm{Pb} + 8\alpha + 8e^- + 6\bar{\nu}_e + 51.7\ \mathrm{MeV}$$
$$^{232}\mathrm{Th} \rightarrow {}^{208}\mathrm{Pb} + 6\alpha + 4e^- + 4\bar{\nu}_e + 42.8\ \mathrm{MeV}$$




Source [1]

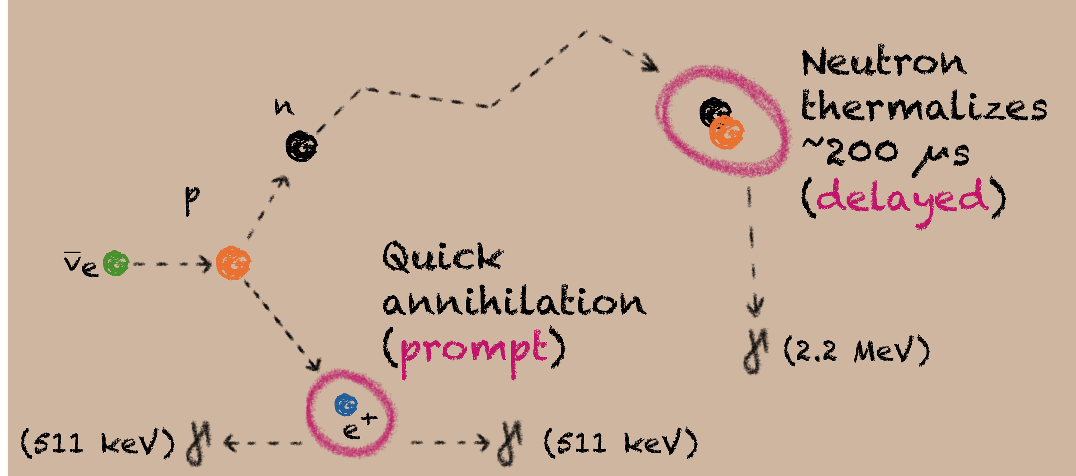
Flux Models
- **Global:** geophysical and geochemical data from compiled database
- **Local:** site-specific geophysical and geochemical data for the local crust surrounding the detector

Geoneutrinos enable us to access the Mantle and constrain geo-models

Geoneutrino flux is very small; therefore, **kiloton-mass detectors** are needed

## How to detect them...

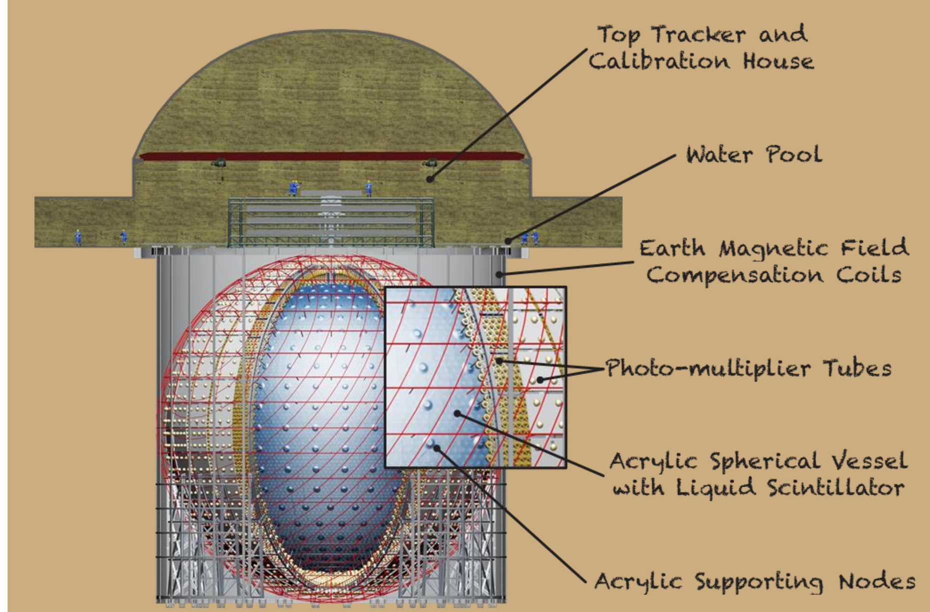
Inverse Beta Decay (IBD): $\bar{\nu}_e + p \rightarrow e^+ + n$




- Positron deposited Energy $E_{dep} \approx E_\nu - 0.782$ MeV
- Only possible for $\bar{\nu}_e$ since is a charged interaction
- Energy threshold @ 1.806 MeV
- Time coincidence essential for background suppression

Selection is based on the pairing of time correlated events

## JUNO Experiment

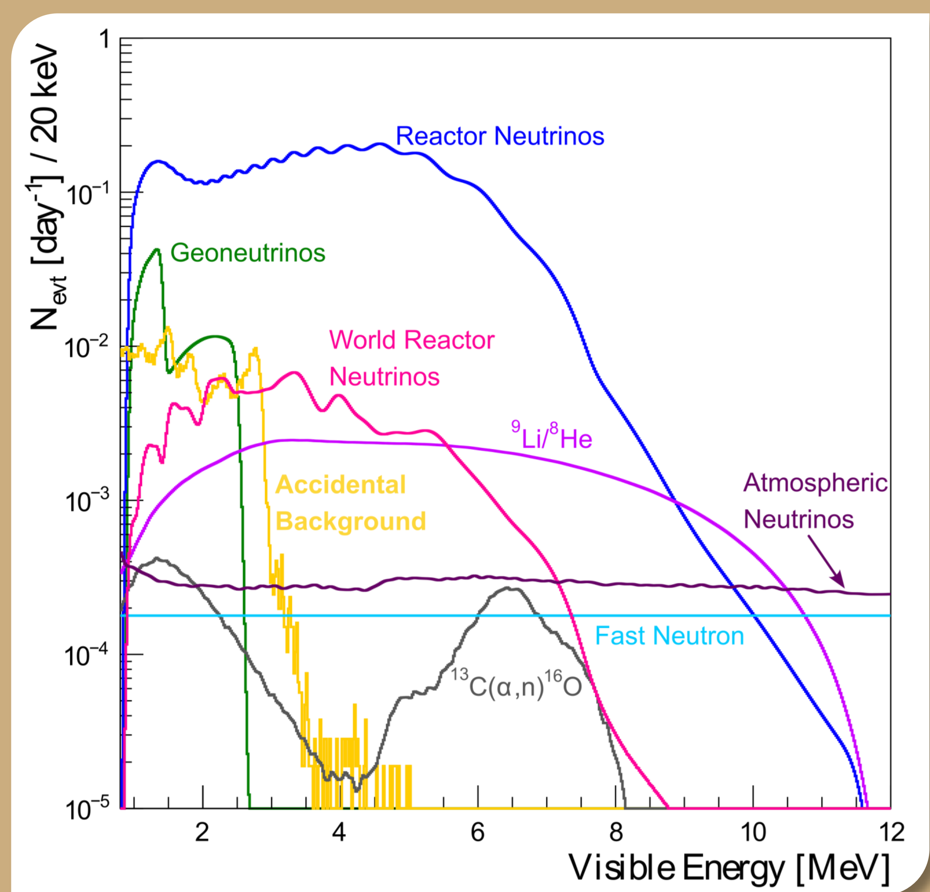



- **J**iangmen **U**nderground **N**eutrino **O**bservatory
- To be completed this year
- **Main objective:** determine the **Neutrino Mass Ordering** with reactor anti-neutrinos. Precise measurement of **oscillation parameters** with sub-percent precision
- Great potential in other topics as **Geoneutrinos**

## Signal and Backgrounds

- **Oscillation parameters** are not constrained on the fitting $\theta_{12}, \theta_{13}, \Delta m^2_{21}, \Delta m^2_{32}$
- **Reactor neutrinos** shape unc. provided by Daya Bay measurements
- **World reactors** consider all those reactors located further than 300 km from JUNO [4]

| | Rate [day$^{-1}$] | Rate unc. | Shape unc. |
|---|---|---|---|
| Geoneutrinos | 1.2 | - | 5% |
| Reactor Neutrinos | 43.175 | - | Daya Bay |
| Accidentals | 0.8 | 1% | - |
| $^9$Li$^8$He | 0.8 | 10% | 10% |
| $^{13}$C($\alpha$,n)$^{16}$O | 0.05 | 50% | 50% |
| Fast Neutron | 0.1 | 100% | 20% |
| World Reactor | 1 | 5% | 5% |
| Atmospheric Neutrinos | 0.16 | 50% | 5% |




- Expected spectral shape of background and signals are generated through analytical and Monte Carlo approach
- Detector response are applied to all spectra
- Shape and rate uncertainties are considered as nuisance parameters in the pull terms

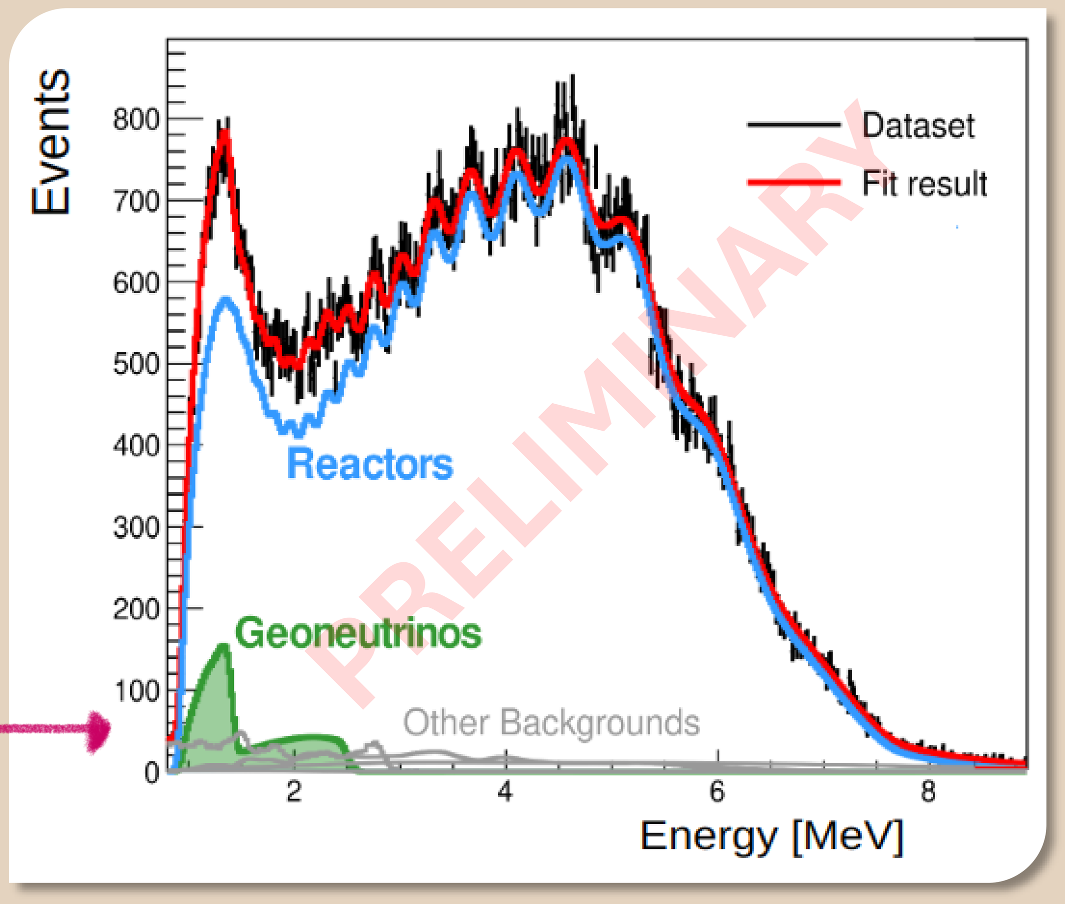
$$\chi^2 = \frac{(y-n)^2}{y + (\sigma_{shape} \cdot y)^2} + \text{Pull Terms}$$

## Total Geoneutrino Signal

| Expected geoneutrino precision (assuming Th/U mass ratio fixed to 3.9) | |
|---|---|
| 1 year | ~22% |
| 6 years | ~10% |
| 10 years | ~8% |

PRELIMINARY

Example of 10 years of exposure using fixed Th/U to model geoneutrino spectrum




Two measuring schemes:
- **Fixed Th/U:** total geoneutrino signal is fitted by assuming a fixed ratio between the abundances of Th and U, corresponding to the chondritic ratio of 3.9
- **Free Th/U:** no assumption is made in the contributions of Th and U, thus each is fitted independently of each other

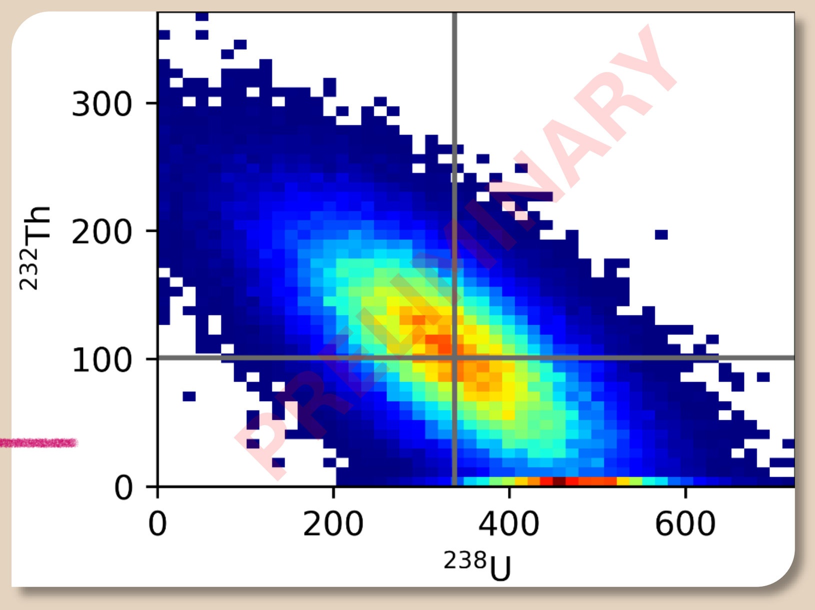
- In just 6 years, we could achieve better precision than KamLand [5] and Borexino [1] measurements, which uses more than 10 years of data
- Individual measurement of U and Th contribution with high statistical significance
- Third complementary geological location

## Independent Th and U contribution

| Expected geoneutrino precision | | |
|---|---|---|
| | 6 years | 10 years |
| $^{232}$Th | ~40% | ~35% |
| $^{238}$U | ~35% | ~30% |
| $^{232}$Th+$^{238}$U | ~18% | ~15% |
| $^{232}$Th/$^{238}$U ratio | ~70% | ~55% |

PRELIMINARY

Anti-correlation nature of U and Th enables a better precision when both signals are combined




## References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2. O. Smirnov. "Experimental aspects of geoneutrino detection: Status and perspectives". Progress in Particle and Nuclear Physics 109 (2019) 103712
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