# Geoneutrinos with opaque scintillators

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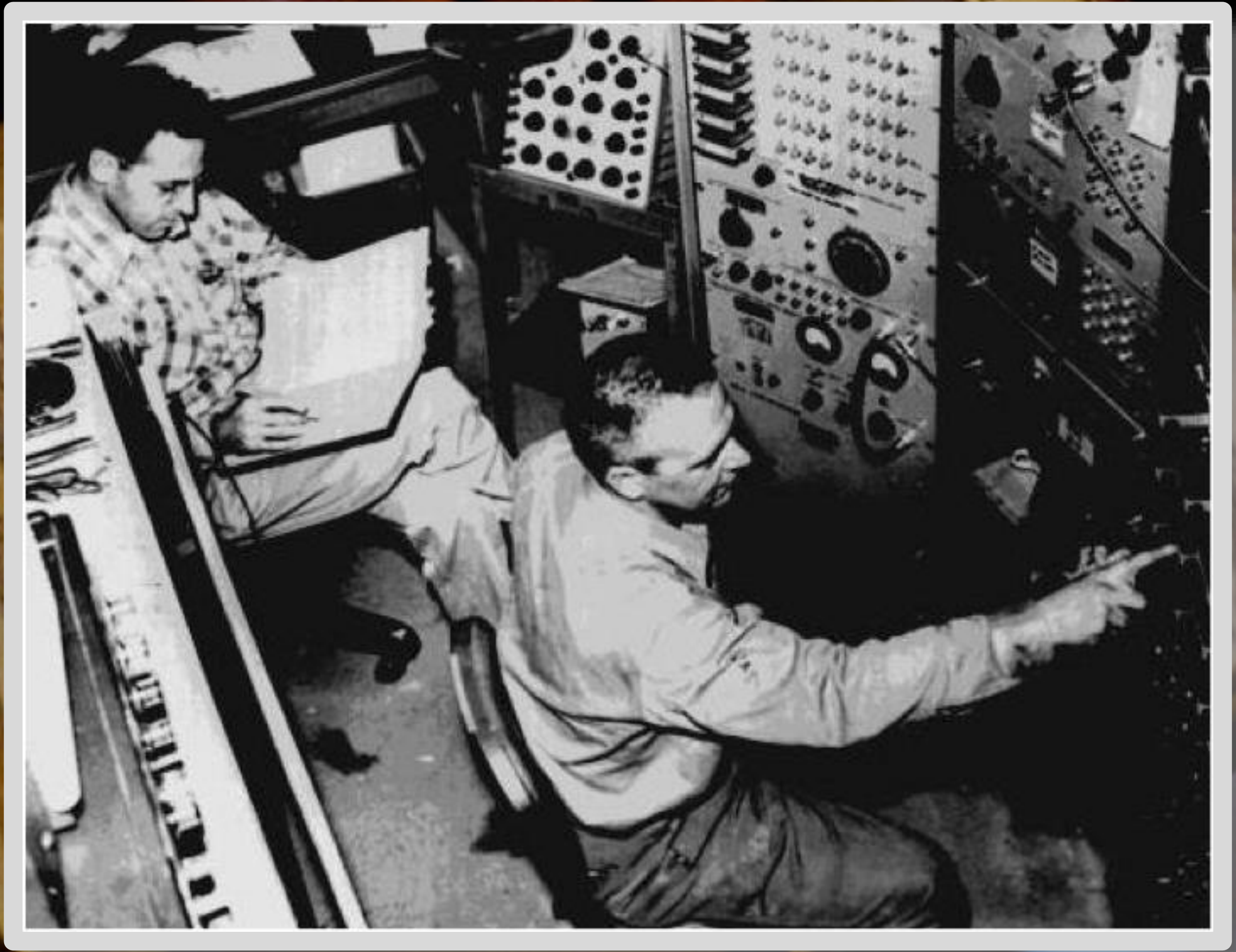
**European Strategy for Particle Physics**

A town hall meeting will be held to discuss inputs from the local community. The agenda includes presentations on various activities from each of the scientific commissions. Time has been allocated for general discussion and for reflections and proposals from early career researchers.


…within the past lie the footprints to the future…

# …1953…



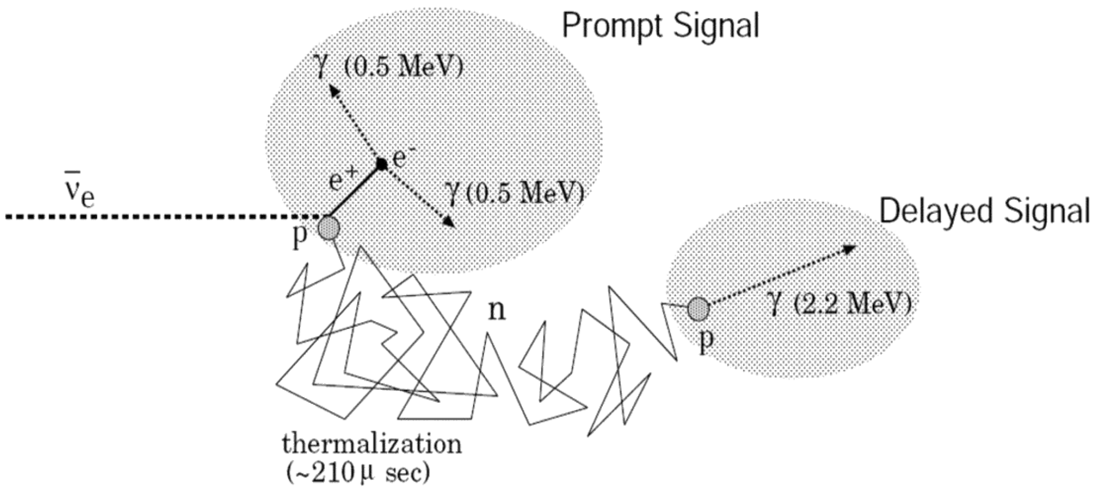
# Inverse Beta Decay (IBD) detection

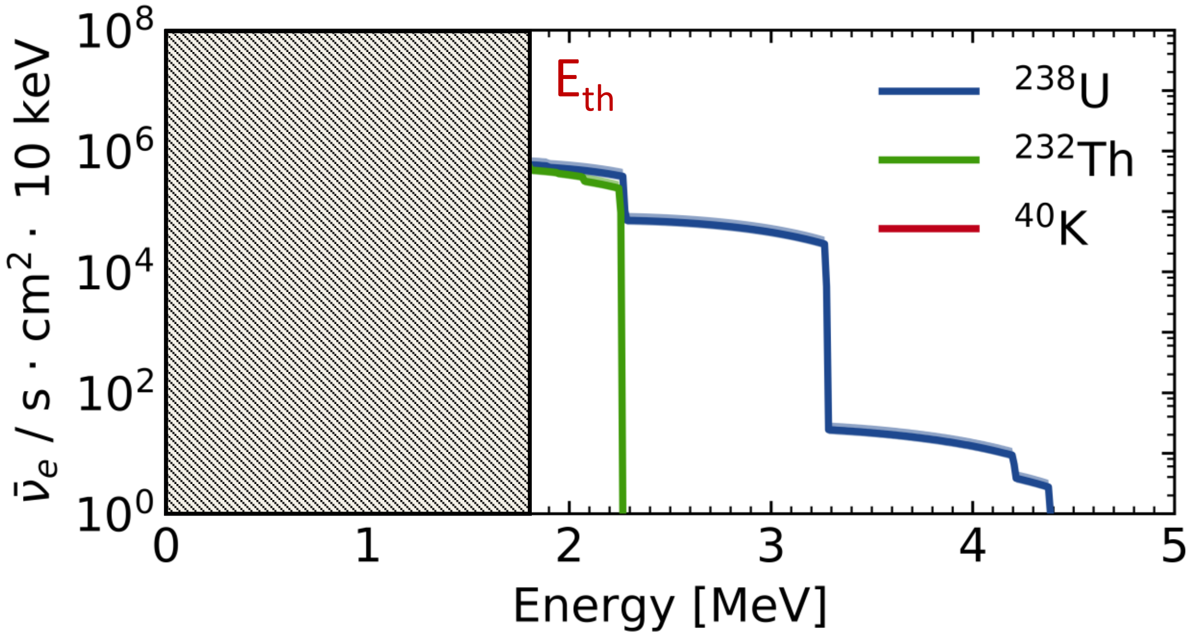
Geoneutrinos are **detected by IBD** in **~kton** Liquid Scintillation Detectors.

$$\bar{\nu}_e + p \rightarrow n + e^+ - 1.806\ MeV$$

Detection requires the coincidence of 2 delayed light signals.

It does not permit to observe $^{40}$K-$\bar{\nu}_e$



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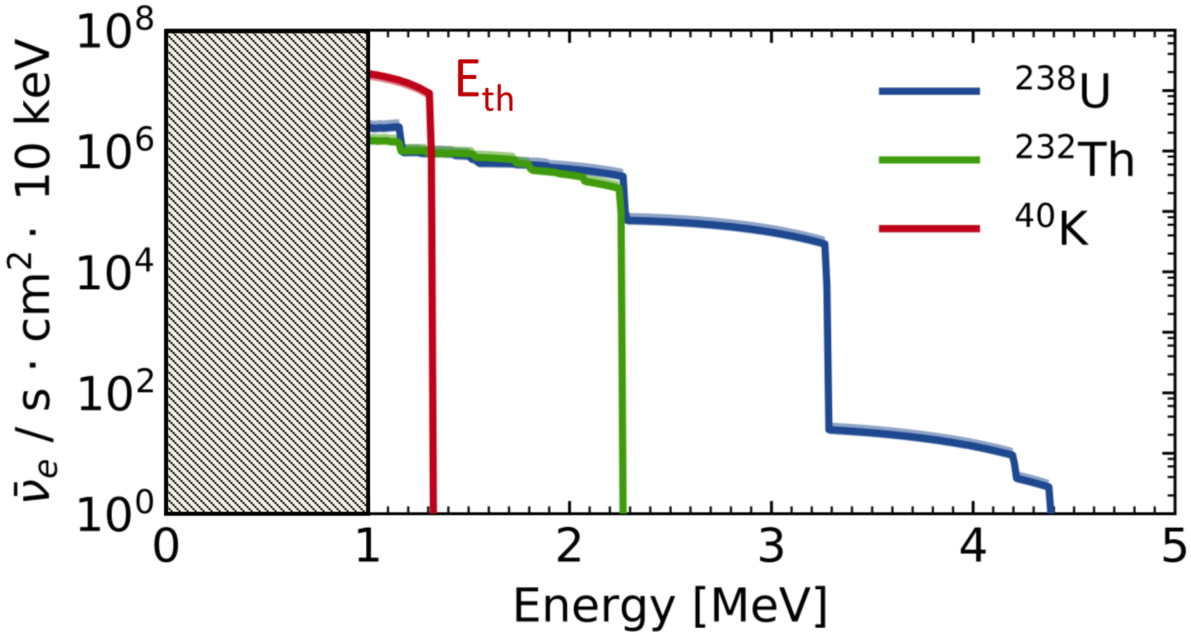
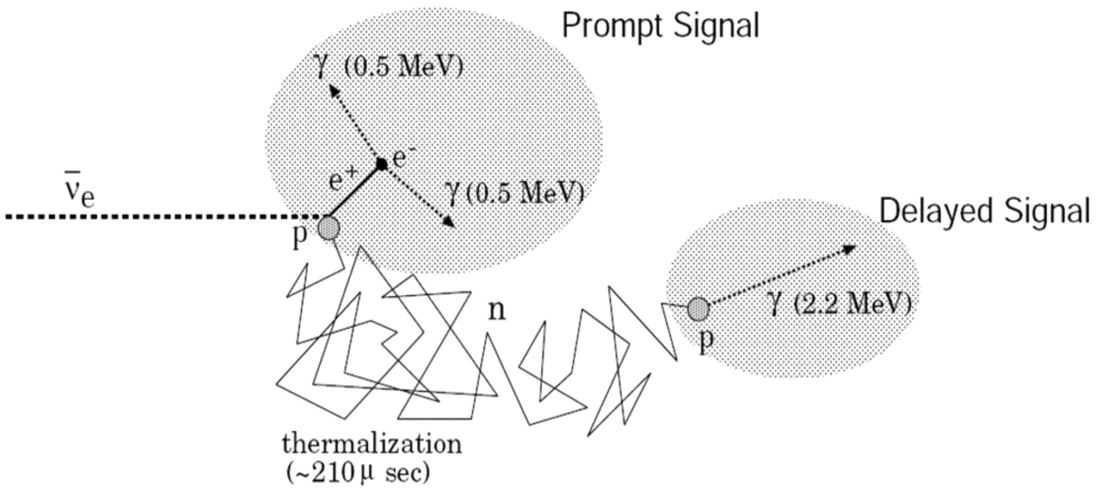



In order to detect $^{40}$K- $\bar{\nu}_e$ we could use:

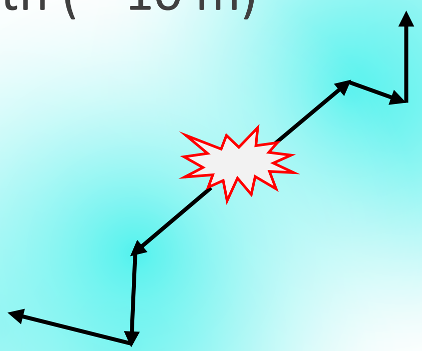
$$\bar{\nu}_e + {}_{Z+1}^{A}Y \rightarrow {}_{Z}^{A}X + e^+ - E_{th}$$

We shall require:

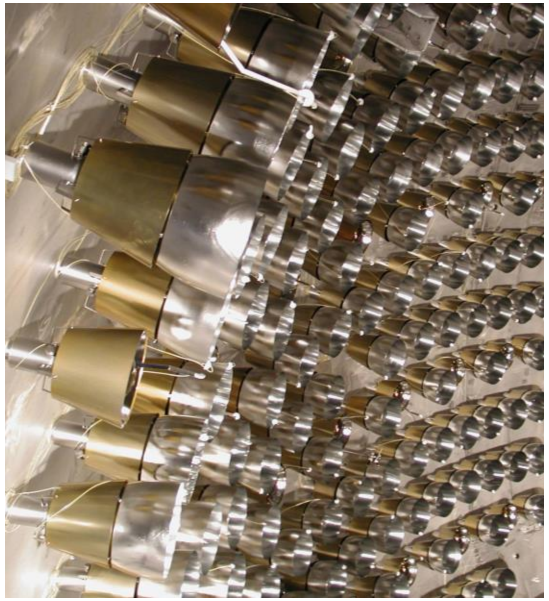
- $E_{th}$ < *1.3 MeV*
- High cross-section
- High Y natural isotopic abundance

# Transparent vs. opaque detector

Very long scattering length (~ 10 m)

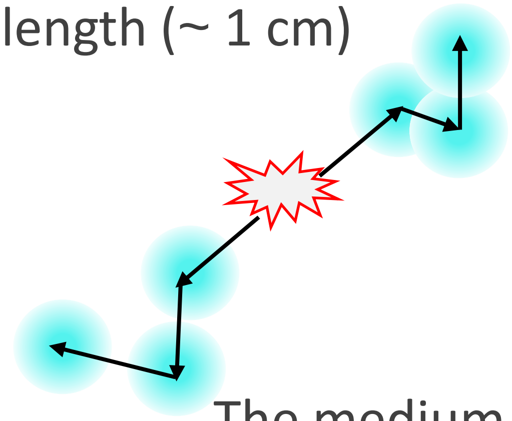


The medium is transparent to scintillation photons

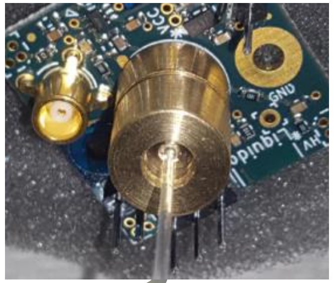


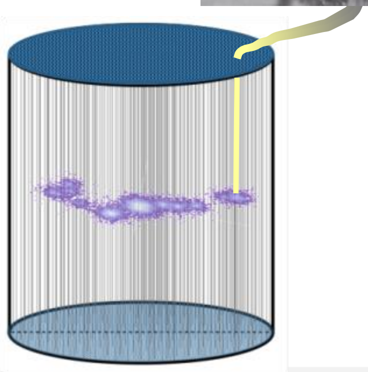
- Scintillation light reaches the surrounding $10^3$-$10^4$ PMTs
- Slow time resolution (~ ns)
- Poor spatial resolution on light deposition (~ 10 cm)
- High photon detection efficiency (~ 20%)

Very short scattering length (~ 1 cm)



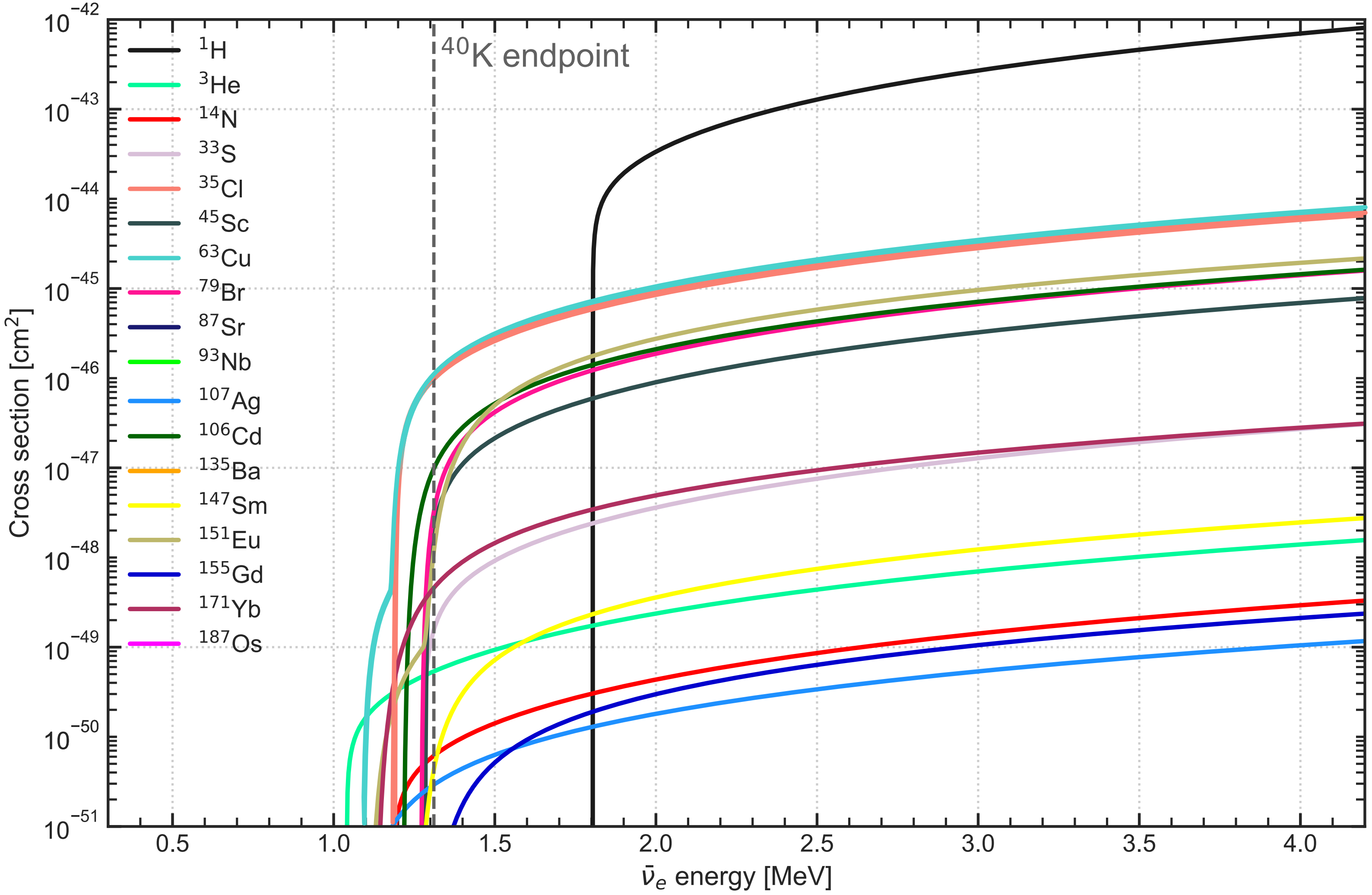
The medium is opaque to scintillation photons



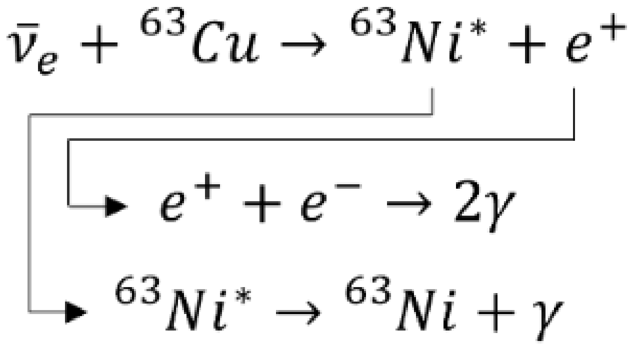


- The light is extracted by an array of optical fibers connected to SiPMs
- Fast time resolution (~ 0.3 ns)
- Excellent spatial resolution on light deposition (~ 1 cm)
- Poor photon detection efficiency (~ 5%)

# IBD cross-sections weighted by isotopic abundance




$^{63}$Cu (Isotopic Abundance = 69%) appears to be a promising target for $^{40}$K geoneutrinos due to its transition to an excited state in $^{63}$Ni* ($E_{MAX}$ = 1.176 MeV; $t_{1/2}$ = 1.67 μs), offering potential double-coincidence capability ($E\gamma$ = 87 keV).




Cabrera et al. - Probing Earth's Missing Potassium using the Unique Antimatter Signature of Geoneutrinos - arXiv:2308.04154

# Expected number of geoneutrino and reactor antineutrino events

**Table 3 | Expected Number of Geoneutrino and Reactor Antineutrino Events.** Antineutrino events estimated using a LiquidO detector located at the Laboratori Nazionali del Gran Sasso (Italy), as an example, and having a mass of 240 kton with 50% Cu loading and considering 10 years of data taking. Full details regarding the calculation of the geoneutrino and reactor antineutrino events rates are described in the Methods section.

| Detection reaction | Energy range | Events / 10 yr / 240 ktons | | | |
|---|---|---|---|---|---|
| | | Reactors | $^{238}U$ | $^{232}Th$ | $^{40}K$ |
| IBD(p) | [1.806 – 3.27] MeV | 19530 | 27750 | 7948 | / |
| IBD($^{63}Cu \rightarrow ^{63}Ni^*$) | [1.176 – 1.311] MeV | 0.2 | 1.1 | 1.1 | 11.7 |

# Why $^{40}K$ is relevant for Earth Science?

- $^{40}K$ contributes up to 20% of Earth's radiogenic heat, which is crucial for geothermal processes and planetary dynamics.
- Measuring $^{40}K$ content would clarify Earth's thermal budget, estimated at around 47 TW of internal power.
- Potassium geoneutrino measurements could solve the “missing potassium” issue, with observed levels estimated at only 1/3 to 1/8 of predictions based on chondrite models.
- Accurate knowledge of potassium would improve understanding of volatile elements' behavior, like H and C, during Earth's formation.
- Measuring potassium geoneutrinos would help resolve the "missing argon" problem, as only about half of the expected $^{40}Ar$ is observed in the atmosphere, closely tied to potassium’s presence in Earth's mantle.