Geo-Neutrino Opportunity in Jinping

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June 5, 2015
Overview

1. Geo-Neutrinos
2. Reactor Neutrinos
3. Background
   - Reactor Background
   - Other Background
4. Geo-Neutrino Opportunity at Jinping
5. Conclusion
Geo-Neutrinos
Geo-Neutrino Introduction

- Compose of $\bar{\nu}_e$
- Low energy ($E_\nu < 3$ MeV)
- Carry information of abundance and spatial separation

![Geo-neutrino signal map](image)

<table>
<thead>
<tr>
<th>Decay Reaction</th>
<th>Final Products</th>
<th>Energy (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{238}\text{U}$</td>
<td>$^{206}\text{Pb} + 8\alpha + 6e^- + 6\bar{\nu}_e + 51.698$</td>
<td></td>
</tr>
<tr>
<td>$^{235}\text{U}$</td>
<td>$^{207}\text{Pb} + 7\alpha + 4e^- + 4\bar{\nu}_e + 46.402$</td>
<td></td>
</tr>
<tr>
<td>$^{232}\text{Th}$</td>
<td>$^{208}\text{Pb} + 6\alpha + 4e^- + 4\bar{\nu}_e + 42.652$</td>
<td></td>
</tr>
<tr>
<td>$^{40}\text{K}$</td>
<td>$^{40}\text{Ca} + e^- + \bar{\nu}_e + 1.311$</td>
<td></td>
</tr>
<tr>
<td>$^{40}\text{K} + e^-$</td>
<td>$^{40}\text{Ar} + \nu_e + 1.505$</td>
<td></td>
</tr>
</tbody>
</table>
Only $\bar{\nu}_e$'s from $^{232}$Th and $^{238}$U exceed the 1.8 MeV IBD threshold.

Distinguishable for the double peak structure of $^{238}$U.
Geo-Neutrino Detection Status


1. Detection via IBD
2. Overwhelming background from reactor $\bar{\nu}_e$
3. Other bkg includes ($\alpha, n$) and accidental bkg
Reactor Neutrinos
Reactor Neutrino Spectrum & World Reactor Map

\[ \phi(E_\nu) = \frac{W_{th}}{\sum_i f_i e_i} \sum_i f_i S_i(E_\nu) \]

1. \( i \) sums over the four isotopes
2. \( W_{th} \) thermal power of a reactor
3. \( f_i \) fission fraction of each isotope
4. \( e_i \) average energy released per fission
5. \( S_i(E_\nu) \) antineutrino spectrum per fission

[IAEA, 2015]
Reactor $\nu$ Flux at Geo-$\nu$ Observatories

\[ \phi(E_\nu) = \sum \phi_i(E_\nu) P_{\bar{\nu}_e \rightarrow \bar{\nu}_e}(E_\nu, L) \cdot \frac{1}{4\pi L} \]

- Assuming eternal close down of all reactors in Japan.
Cross section from [P. Vogel, 1999].

Assuming eternal close down of all reactors in Japan.
\( \alpha, n \) & Accidental

\(^{13}\text{C}(\alpha, n)^{16}\text{O} \text{ as main bkg in \textit{oil-LS}}\)

1. \( \alpha \) from Natural Radioactivity
2. \(^{13}\text{C} \text{ from LS (Oil base: 33.68\% } \times 1\%, \text{ Water base: } \approx 0)\)

\(^{18}\text{O}(\alpha, n)^{21}\text{Ne} \text{ as main bkg in \textit{water-LS}}\)

1. \(^{18}\text{O} \text{ from water (Oil base: } \approx 0, \text{ Water base: } 33.3\% \times 0.200\%)\)

[E. Sanshiro, 2006]

For similar alpha radioactivity as Borexino, the \((\alpha, n) \text{ bkg} \) is estimated to be \( \sim 1 \text{ (0.2) / kton / 1500 days} \).

For similar radioactivity as Borexino and KamLAND, the \textit{acc bkg} is estimated to be \( \sim 1 \text{ / kton / 1500 days} \).
1. **Least** reactor neutrino background

2. **Discrimination** between U and Th geo-neutrinos.
1. **Least reactor neutrino background**
   Reactor: 10.7 / kton / 1500 days

2. **Mainly crustal geo-neutrino:**
   238U: 123.8 / kton / 1500 days
   232Th: 30.6 / kton / 1500 days

3. **Discrimination between U and Th geo-neutrinos.**
   Distinguishable 2 peaks of Uranium.
References


The End
Backup Page
Nuclear Reaction Bkg

$(\alpha, n)$ in LS

![Graph showing nuclear reaction cross sections](image)

<table>
<thead>
<tr>
<th>Target</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^1\text{H}$</td>
<td>99.985%</td>
</tr>
<tr>
<td>$^2\text{H}$</td>
<td>0.015%</td>
</tr>
<tr>
<td>$^3\text{H}$</td>
<td>-</td>
</tr>
<tr>
<td>$^{12}\text{C}$</td>
<td>98.90%</td>
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<tr>
<td>$^{13}\text{C}$</td>
<td>1.10%</td>
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<tr>
<td>$^{14}\text{C}$</td>
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<tr>
<td>$^{14}\text{N}$</td>
<td>99.634%</td>
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<tr>
<td>$^{15}\text{N}$</td>
<td>0.366%</td>
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<tr>
<td>$^{16}\text{N}$</td>
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</tr>
<tr>
<td>$^{16}\text{O}$</td>
<td>99.762%</td>
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<tr>
<td>$^{17}\text{O}$</td>
<td>0.038%</td>
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<tr>
<td>$^{18}\text{O}$</td>
<td>0.200%</td>
</tr>
<tr>
<td>$^{19}\text{O}$</td>
<td>-</td>
</tr>
</tbody>
</table>

[E. Sanshiro, 2006]