First calculation of cosmic-ray muon spallation backgrounds for MeV astrophysical neutrino signals in Super-Kamiokande

Shirley Li and John Beacom
Center for Cosmology and AstroParticle Physics, Ohio State University

Neutrino astrophysics opportunities in 6-30 MeV

Solar day-night effect

Diffuse supernova neutrino background

Spallation backgrounds are overwhelming

Signal: ν + e → ν + e
Background: Muons break nuclei, Nuclei beta decay.
Above 6 MeV, the backgrounds are dominated by cosmic-ray muon induced spallation.

Cosmic-ray muons lose energy and produce secondaries
The average muon energy in Super-K is 270 GeV.
Muons make lots of secondary particles through pair production, bremsstrahlung, ionization, and photonuclear interaction.

We calculated the isotope yields using FLUKA

Calculated isotope yields

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Half-life (s)</th>
<th>Decay mode</th>
<th>Yaw (×10^{-1}/cm^2)</th>
<th>Primary process</th>
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</thead>
<tbody>
<tr>
<td>16O</td>
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<td>13C</td>
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<td>β^- (62%), β^- (38%)</td>
<td>82</td>
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<td>β^-</td>
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Yields compared to Super-K measurements

Good agreement with spallation background time distribution.
The fact that our results match BOTH the time and energy distributions is a powerful indication that they are accurate.
Time distribution: tests the relative yields among isotopes.
Energy spectrum: tests the overall normalization.

Different isotopes are made by different secondaries
The secondaries reach different distances.
The secondaries interact at different energies.

Because different isotopes are made by different secondary particles, they have different distance distributions.

8B is dominant at higher energies, and is primarily made by pions.
14N is dominant at lower energies, and is primarily made by neutrons.
They differ by a factor of 1.7 in radius, which is a factor of 3 in cylindrical volume, which affects cut efficiency.

Conclusions
We demonstrated that a theoretical calculation of spallation is possible, with an accuracy of a factor of 2, while the yields vary by orders of magnitude.
There are correlations among secondary particles and isotopes, and among different isotopes. Using this information can lead to stronger cuts.
There is more information to be gained by separating each isotope, instead of combining all of them together.

References

Contact
Shirley Li
CCAPP, Department of Physics, The Ohio State University
Email: li.1287@osu.edu

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