UCRL-PROC-206435

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**September 9, 2004**

Neutrino 2004, Paris, France, June 13-19, 2004

# Cosmic-Ray Production of $^{60}$Co in Double Beta-Decay Source Materials

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An important background source in double beta-decay experiments is due to the presence of long-lived cosmogenic nuclides in the source materials. Cosmic-ray induced spallation reactions on medium to large mass nuclei can produce a wide range of radioisotopes. $^{60}$Co is a particularly challenging case because of its large total decay energy (2.824 MeV), its $\beta$-decay endpoint energy (0.318 MeV), and its coincident $\gamma$ rays at 1.173 and 1.332 MeV [1]. If $^{60}$Co is present in an active detector, then its decays can produce events from several different combinations of the $\beta$ and $\gamma$ rays. We measured the cross sections for the production of $^{60}$Co in $^{nat}$Mo and $^{nat}$Te at the proton energy of 1.85 GeV and in $^{nat}$Ge, $^{nat}$Mo, and $^{nat}$Te at the proton energy of 0.8 GeV. The 1.85-GeV irradiation was performed in 1992 at LBNL's Bevalac facility [2]. These targets were bombarded in air in a stack together with sheets of acrylic which were used to monitor the total beam exposure through the production of $^{11}$C from the C and O in the plastic. Eleven years later, these targets were gamma-ray counted at LBNL's Oroville Dam Low Background Facility. The 0.8 GeV irradiations were performed in April, 2004, at the Los Alamos Neutron Science Center at LANL. The Ge, Mo, and Te targets were sandwiched between polyethylene and aluminum sheets that were used to monitor the total beam exposure through the production of $^{7}$Be and $^{22}$Na, respectively. Each target stack was bombarded separately in air. The targets and monitor foils were counted approximately one month later at LBNL. From the yields of $^{60}$Co $\gamma$ rays observed from each target, measured $\gamma$-ray detection efficiencies, inferred proton fluences, and target thicknesses, we determined the $^{60}$Co production cross sections shown in Table 1. Semi-empirical spallation cross sections were estimated for each stable isotope contained in the targets [3]. The resulting $^{60}$Co production cross section from each isotope was multiplied by the appropriate isotopic abundance and then summed over all the stable isotopes to obtain the effective cross section for the natural isotopic composition targets used in our experiments.

Table 1. $^{60}$Co production cross sections as determined in our experiments and as estimated using an updated semi-empirical formalism [3].

| Energy (GeV) | Target | $\sigma_{expt}$ (mb) | $\sigma_{calc}$ (mb) |
|---|---|---|---|
| 0.8 | Ge | $8.5 \pm 1.3$ | ---- |
| 0.8 | Mo | $0.77 \pm 0.11$ | 0.90 |
| 0.8 | Te | $< 0.5$ | 0.22 |
| 1.85 | Mo | $1.45 \pm 0.20$ | 2.78 |
| 1.85 | Te | $0.63 \pm 0.15$ | 0.85 |

The overall agreement between the experimental results and the semi-empirical estimates is reasonably good considering that the cross section for the production of $^{60}$Co is a very small fraction of the total reaction cross section at these energies. While the importance of $^{60}$Co backgrounds will be different for each $\beta\beta$ decay experiment, based on the present cross section results, and estimates of cosmic ray exposure of detector materials, it appears that $^{60}$Co should not be a major source of background in the next generation of double beta decay experiments.

## ACKNOWLEDGEMENTS

This work was supported by the U. S. Department of Energy under contract numbers DE-AC03-76SF00098 (LBNL) and W-7405-ENG-36 (LANL).

## REFERENCES

1. R. B. Firestone and V. S. Shirley, *Table of Isotopes*, *8th Ed.*, Wiley, New York (1996).
2. D. Bardayan *et al.*, Phys. Rev. C 55, 820 (1997).
3. R. Silberberg, C. H. Tsao, and A. F. Barghouty , *Astrophys. Journ.* 501, 911 (1998).

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This work was performed under the auspices of the U. S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.