COSMIC RAY HISTORY DERIVED FROM THE ^{54}Mn, ^{56}Ni, and ^{144}Pm CHRONOMETERS

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Detailed information on the history of cosmic rays within our Galaxy can be determined by comparing the cosmic-ray abundances of long-lived radioactive isotopes to those of their stable neighbors. Due to their interactions with the interstellar medium, high-energy cosmic ray nuclei are fully stripped of their atomic electrons. This turns nuclei such as ^{7}Be, ^{53}Mn and ^{145}Pm, which decay in the laboratory via electron capture, into stable nuclei as cosmic rays. Because of their larger EC decay energies, it is possible for nuclei such as ^{54}Mn, ^{56}Ni, and ^{144}Pm to decay by β^+ emission. By combining observations of the cosmic-ray abundances of these isotopes with measurements of their β^+ decay half lives, the mean confinement time of cosmic rays in our galaxy and the time interval between nucleosynthesis and cosmic ray acceleration can be deduced.

We performed three experiments on GAMMASPHERE to search for the astrophysically interesting β^+ decay branches of ^{54}Mn, ^{56}Ni, and ^{144}Pm. We placed a chemically purified source of each isotope at the normal target position and searched for the characteristic signature of the β^+ decay of each isotope.

In the case of ^{54}Mn, we observed the back-to-back 511-511 keV coincidences produced by the ground-state to ground-state β^+ decay. A careful analysis of data obtained from 97 hours of source counting and 61 hours of background showed a net signal of 24±10. From this result we determined this decay branch to be $2.2\text{x}10^{-7}$% [1]. The corresponding log *ft* for this transition is 14.5. Assuming that the β^- decay of ^{54}Mn to the ground state of ^{54}Fe has this same log *ft* , we infer that the β^- decay half-life (and hence the cosmic ray half-life) of a bare ^{54}Mn nucleus is 7.6 $\text{x}10^{5}$ yr. This result is in good agreement with the value of 1-2 $\text{x}10^{6}$ years deduced by DuVernois [3] by combining his measurements of the isotopic composition of cosmic-ray manganese with the confinement time of 15 x 10^{6} years derived from other chronometers. This implies that the confinement time of iron-group cosmic rays is the same as that of the lighter cosmic-ray nuclei.

For ^{144}Pm, we searched for 511-511-697 keV coincidences that would be produced by the β^+ decay to the $J^p = 2^+$ first excited-state in ^{144}Nd. While we did not observe this decay mode, we set a 90% confidence level upper limit on the branch of $7.4\text{x}10^{-6}$% [2] which is approximately a factor of 10 lower than the previous limit.

For ^{56}Ni, we measured the energy spectrum of positrons in coincidence with 511-511-158 keV gamma rays that would be produced by the β^+ decay to the $J^p = 3^+$ first excited state in ^{56}Co. Analysis of the data from this experiment is now in progress.

Footnotes and References

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