^{53}Mn in Extraterrestrial Matter

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1. Production of ^{53}Mn

Since the earth's surface is shielded by the atmosphere from cosmic rays, most natural ^{53}Mn found on earth is produced in extraterrestrial matter, mainly by spallation of high energetic (primary and secondary) cosmic rays on iron. Measuring the content of such cosmogenic radioisotopes in samples of extraterrestrial origin yields information about their irradiation history and also about the time dependence of the cosmic ray flux. Because of its very long half live (3.7 My) ^{53}Mn is of special interest, because one can obtain information on a time scale up to ≈10 My.

In meteorites the production of cosmogenic nuclides starts, when they are separated from their mother bodies in collisions and are not longer shielded from cosmic rays by higher layers. The production stops, when they are entering the earth's atmosphere and are shielded again. As the surface of a meteorite is ablated in the atmosphere, the nuclides produced by the low energetic solar cosmic rays near the surface get also lost. Therefore the nuclides in a meteoritic sample found on earth are produced for the main part by the high energetic galactic cosmic rays. If the half live of a cosmogenic radionuclide is long enough for its concentration not to be in saturation, one can determine from this concentration the irradiation age of the meteorite. The flux of secondary protons and neutrons is built up in the depth, therefore the production rate is also depth dependent. Because of different energy and projectile (p or n) dependences of the production rates, the slope of the depth profiles of comogenic nuclides are also different. Therefore one can determine from the concentration of a set of radionuclides (e.g. ^{10}Be, ^{26}Al, ^{53}Mn) in a small sample the preatmospheric size of the meteorite and the preatmospheric depth of this sample.

The dominant input of extraterrestrial matter on earth is due to cosmic dust particles (≈98 % [1]). With a diameter in the μm range there is no possibility for a build up of a significant secondary flux. The production is dominated by particles with lower initial energy, i.e. by the low energetic solar cosmic rays, while in meteorites most reactions are induced by secondary galactic cosmic rays. ^{53}Mn produced in cosmic dust is accumulated e.g. in deep sea manganese crusts. As precipitation rate of the crusts is known, one can determine the total ^{53}Mn input per time unit from their ^{53}Mn content. Assuming a constant solar cosmic ray flux in the past, the total input of extraterrestrial dust on earth can be obtained from ^{53}Mn measurements.

2. Measurement of ^{53}Mn

With exception of few measurements with totally stripped ions [4] ^{53}Mn is not yet established as an AMS isotope, mainly because of the high background of the disturbing stable isobar ^{53}Cr. As already reported in [2,3], the gas-filled analyzing magnet system GAMS is capable of extremely sensitive AMS measurements of heavy longlived radioisotopes. Besides the excellent separation of isobars in their position at the exit of the gas-filled magnet, the counting rate in the detector can be reduced about two orders of magnitude adjusting the magnetic field in such a way, that most ^{53}Cr ions arrive outside the detector. Therefore very efficient and sensitive measurements at a modest counting rate became possible.

Injecting negative hydride ions instead of oxyde ions into the tandem by spraying hydrogen on a metallic manganese sputter target yielded no further isobaric supression of the disturbing isobar ^{53}Cr. Because the maximum currents achieved were about one order of magnitude lower, in all measurements MnO^- ions were injected. A time-of-flight measurement for isotopic discrimination is in this case not necessary, because of a suffcient suppression of the stable ^{55}Mn ($\Delta A = 2$) by magnetic deflections in the beamline, the Wien filter, and the separation of the isotopes by their energy loss signals in the detector.

Although the contamination of the disturbing isobar ^{53}Cr in the samples could not be suppressed chemically better than ≈10 ppm, a sensitivity in the range of a few times 10^{-13} ^{53}Mn/Mn was achieved by further optimizing the isobaric and isotopic separation. With these it became for the first time possible, to measure routinely ^{53}Mn in meteorite samples: for a typical meteoritic sample (150 mg meteorite, 3 mg ^{55}Mn) with a ^{53}Mn/Mn ratio of 10^{-10} it takes about five minutes to accumulate 100 ^{53}Mn events.

In a first measurement of a deep sea manganese crust two ^{53}Mn events were detected, corresponding to a ^{53}Mn/Mn ratio of 2×10^{-12}. This value is in good agreement with an input of extraterrestrial matter of 5000 t/a, estimated in [5].

References

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