Measurement of the Excitation Function for the Production of the Cosmogenic Radionuclide ^{53}Mn on Iron

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The cosmogenic radionuclide ^{53}Mn ($T_{1/2}$ = 3.7 My) is of special interest in the research of extraterrestrial matter because of several reasons:

(i) compared to other cosmogenic radionuclides (e.g. ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl) it has a very long half-life. Therefore, ^{53}Mn activities in extraterrestrial matter give information on its irradiation history over a time span in the order of 10^7 y.

(ii) ^{53}Mn is produced dominantly on iron and only to a few percent on nickel. Heavier target elements have too low abundances in extraterrestrial matter to contribute significantly to the ^{53}Mn production. For this reason, the comparision of measured data with theoretical calculations is more reliable than for radionuclides with lower mass, which are produced on much more different target elements.

(iii) As argon is the heaviest element having a significant abundance in the earth's atmosphere, there is no background from atmospheric cosmogenic production.

Up to now, there where only limited data for the cross section of the production reaction ^{nat}Fe(p,2pxn)^{53}Mn [1–7] as shown in fig. 1. Nearly all data are for proton energies below 50 MeV. For energies at the expected peak of the excitation function no measurements are existing. In addition, the only two experimental data points for high energies (660 MeV and 730 MeV, respectively) differ by a factor of two.

To achieve a more complete data set for the excitation function we irradiated 16 iron foils with protons in the energy range between 17 MeV and 1.6 GeV.

E [MeV]	σ [mbarn]	laboratory
17.2 ± 1.9	74 ± 9	U
30.6	56 ± 9	PSI
38	31 ± 5	PSI
46.8	107 ± 17	U
58.6	199 ± 26	U
66.3	146 ± 23	PSI
80.5	117 ± 13	U
84.3	93 ± 24	U
90.7	102 ± 14	U
115	76 ± 13	U
178	64 ± 10	U
397	35 ± 5	S
599	35 ± 5	S
800	46 ± 7	S
1200	35 ± 5	S
1600	32 ± 5	S

Table 1: Resulting cross sections for the reaction ^{nat}Fe(p,2pxn)^{53}Mn. The irradiations were performed at:
U: Cyclotron at Svedberg Laboratory, Uppsala
PSI: Cyclotron at Paul-Scherrer-Institut, Villigen
S: Synchrotron at Laboratoire Nationale Saturne, Saclay

After adding 4 mg of stable manganese carrier the iron foils were dissolved in HNO_3 and manganese was extracted. The ^{53}Mn/^{55}Mn ratios were measured via accelerator mass spectrometry at the gas-filled analyzing magnet system GAMS [8].

For a calibration of these measurements a new ^{53}Mn standard with a higher accuracy had to be produced. For this purpose a vanadium foil was irradiated with α particles at the Munich tandem. Since the cross section for the reaction ^{51}V(α,2n)^{53}Mn is not known, the total number of produced ^{53}Mn nuclei was determined by an in-beam measurement of their deexitations. This approach yielded a standard with an uncertaincy in the ^{53}Mn/^{55}Mn ratio of only 5%. The cross section was determined to 1.27 barn at 35 MeV.

The results of the measurements are shown in table 1 and fig. 1. The errors are mostly due to systematics of the AMS measurements, e.g. instabilities of the ion source. The statistical errors of all measurements are less than 1%.

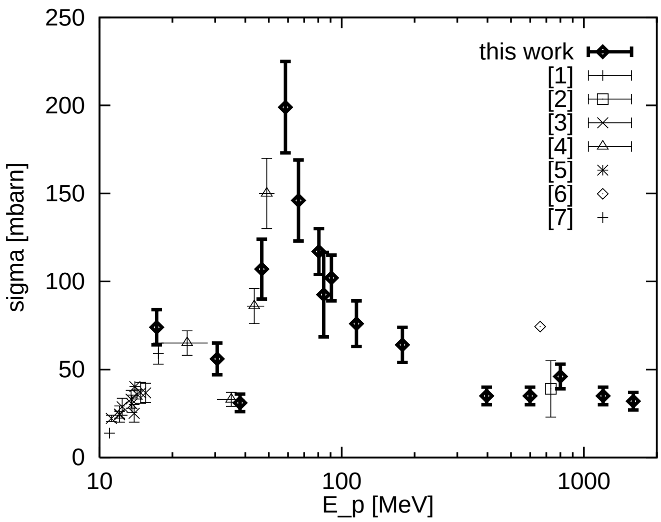

Fig. 1: Experimental excitation function for the reaction ^{nat}Fe(p,2pxn)^{53}Mn.

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