First Systematic AMS Measurements of ^{60}Fe in Meteorites ◇

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In meteorites cosmogenic radionuclides are produced by spallation reactions induced by cosmic ray particles. Measuring a set of these radionuclides gives information about the irradiation age of the meteorite, its terrestrial age, its preatmospheric size, the preatmospheric depth of the sample and may indicate a complex irradiation history. It is obvious that the more radionuclides are measured, the more information one can obtain.

Since the half-life of ^{60}Fe (1.49 ± 0.25 Myr [1]) is very similar to that of ^{10}Be (1.6 Myr), an isotope which can be measured very easily with AMS, the ratio ^{10}Be/^{60}Fe yields information independent on saturation effects or radioactive decay.

^{60}Fe is produced mainly on the target nuclides ^{62}Ni and ^{64}Ni. They have natural abundance of only 3.63 % and 0.93 %, respectively, i.e. the production rate of ^{60}Fe is very low. Furthermore stable iron is typically an order of magnitude more abundant in meteorites than nickel. For that reason one can expect in meteorites only ^{60}Fe/Fe ratios of the order of 10^{-14}.

Up to now there where only two attempts to measure ^{60}Fe. Already in the 60s Goel and Honda have measured the decay of ^{60}Co, the daughter of ^{60}Fe [2]. For this purpose the iron from a 2.2 kg sample of the iron meteorite Odessa was chemically extracted. After five years cobalt has been extracted and counted. The big advantage of an AMS measurement is, that samples of a few mg are sufficient and there is no need to wait for a built-up of a ^{60}Co activity. On the other hand the ^{60}Fe/Fe ratio in meteorites is as low, that ^{60}Fe was detected via AMS only once at the Argonne National Laboratory in the iron meteorite Treysa [3]. (For the results see tab. 1 and fig. 1)

Having improved our gas-filled analyzing magnet system GAMS [4] we are able to measure ^{60}Fe with a high efficiency down to ratios of $^{60}\mathrm{Fe/Fe} < 10^{-15}$. Recently we have performed first measurements of the iron meteorites Dermbach and Tlacotepec and the stony iron meteorite Emery. Although the ^{60}Fe concentrations have been very low, a correlation to the nickel content of the meteorites can be seen (see fig. 1 and 2). The run time of each measurement has been about 1 hour. Since we are not limited by background or counting rate it is possible to gain a factor of 5–10 in the ^{60}Fe rate by optimizing the beam current and the transmission.

Our data are in good agreement with first calculations of the ^{60}Fe production in meteorites (see fig. 2), although for the production cross sections there exist only very few experimental values. By determining these cross sections from already irradiated nickel targets [5], these calculations will become more reliable and it seems therefore possible to establish ^{60}Fe in the meteorite research.

	^{60}Fe events	^{60}Fe/Fe $\times 10^{-14}$	dpm/kg Ni
Dermbach*	60	6.3 ± 1.1	0.8 ± 0.2
Tlacotepec*	23	2.8 ± 0.7	1.4 ± 0.4
Emery*	10	1.5 ± 0.5	1.6 ± 0.6
Treysa [3]	1	$3^{+6.9}_{-2.5}$	$2.8^{+6.4}_{-2.3}$
Odessa [2]	decay	10 ± 3	12.5 ± 2.8

Table 1: Measured ^{60}Fe activities in meteorites (* this work). For the error of the Treysa measurement with only one event a Poisson distribution with a confidence level of 68 % was used, the errors of the AMS measurements are $1\,\sigma$ statistical error plus 10 % systematic error plus the error of the half life.

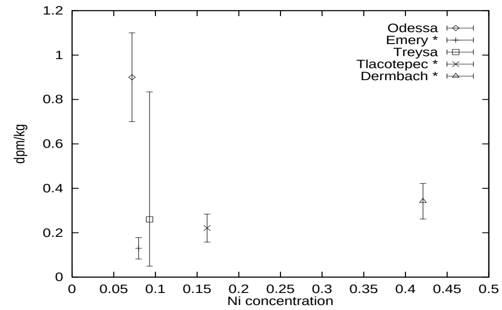

Fig. 1: Measured ^{60}Fe activities (decays per minute and kg of meteorite) in meteorites versus their nickel concentration (* this work). For Dermbach, Tlacotepec and Emery a clear correlation can be seen. Within the error bars our data are consistent with the Treysa activity [3] but in contradiction to the value measured for Odessa [2]

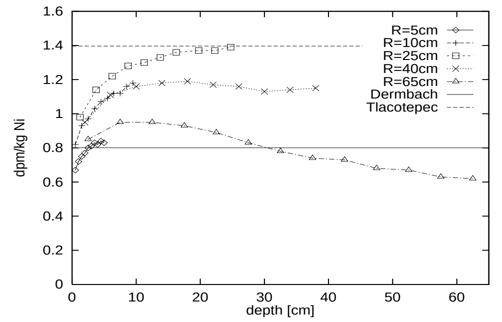

Fig. 2: ^{60}Fe depth profiles (dpm/kg **Ni**) in iron meteorites of different sizes and an irradiation time long enough for ^{60}Fe to be in saturation. The data are calculated with an Monte-Carlo code [5]. The differences are due to the size and depth dependence of primary and secondary cosmic ray flux. The horizontal lines are the measured values for the iron meteorites Dermbach and Tlacotepec.

References

[1] W. Kutschera *et al.*, Nucl. Instr. Meth. **B5** (1984) 430
[2] P.S. Goel and M. Honda J. Geophys. Res. **70** (1965)
[3] M. Paul *et al.*, Nucl. Instr. Meth. **B52** (1990) 315
[4] K. Knie *et al.*, Nucl. Instr. Meth. **B123** (1997) 128
[5] R. Michel *et al.*, Nucl. Instr. Meth. **B113** (1996) 434

◇ We would like to thank the Naturhistorisches Museum, Berlin, for providing a sample of the Dermbach meteorite